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March 2013

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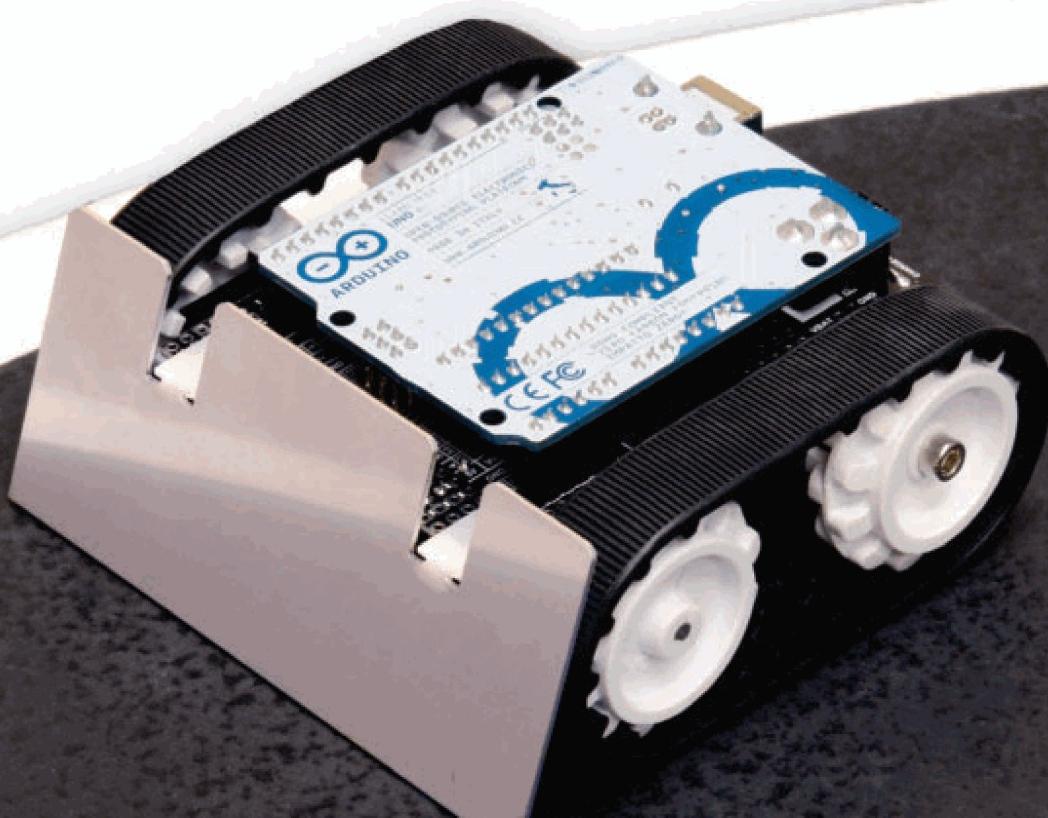
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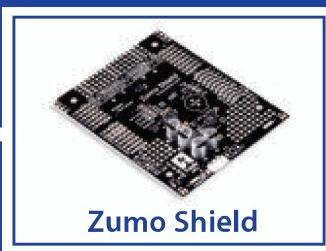
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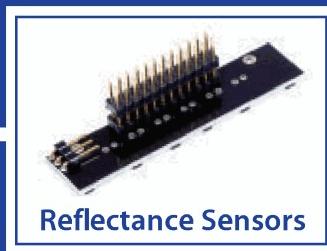
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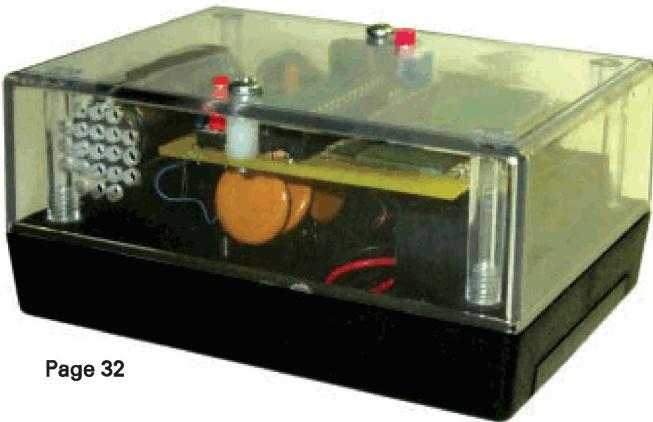
## Build and customize your Zumo.

Put your Arduino or compatible controller on the right tracks with the Zumo chassis and Arduino shield! The Zumo is a small, tracked robot platform that works with a variety of micro metal gearmotors to allow for a customizable combination of torque and speed. Add a Zumo shield, which includes a dual motor driver, buzzer, and three-axis accelerometer and compass, to make an Arduino-controlled robot that can really throw its weight around!



Zumo Chassis Kit

# March 2013



Page 32

## Projects & Features

### 32 A Recording Radiation Counter

Are you exposed? This unit detects and displays levels of radiation, plus you can record months of data to keep track of just how toxic areas may be or become.

■ By Ron Newton

### 40 Introducing Wi-Fi With the PIC 32-bit Micro Experimenter

Get ready to use your Experimenter to communicate with remote Wi-Fi sensors.

■ By Tom Kibalo

### 50 The DHT22 Humidity/Temperature Sensor Demystified

Keeping tabs on relative humidity and temperature is important in a variety of situations. The DHT22 is a recent contribution to the lineup of joint humidity/temperature sensors, and is particularly attractive to DIYers thanks to its low cost. Uncover its secrets to get it working for you.

■ By Thomas Henry

### 54 Raspberry Pi, Anyone?

Get a piece of this popular DIY action by learning how to cook up your own RPi to start experimenting with.

■ By Craig A. Lindley

## Columns

### 10 TechKnowledgey 2013

*Events, Advances, and News*

*Slicing with sound, wireless storage for eight mobile devices, a rival for GPS, and a way to never lose anything again are just some of the interesting tidbits you can catch up on this month.*

### 14 The Spin Zone

*Adventures in Propeller Programming*

Pick a Card or ... Abort!!!

*Learn how to make the best use of the abort coding feature to create programs with robust error handling.*

### 20 Q & A

*Reader Questions Answered Here*

*Solar power for microcontrollers, touch switches, tuned circuit values, remote tester problems, and a tutorial on transistor modeling are covered this month.*

### 60 Smiley's Workshop

*Programming • Hardware • Projects*

The Arduino Proto Shield Alarm Clock — continued. This time, we'll dig deeper into the software for our Arduino based design to see what really makes it tick.

### 68 Near Space

*Approaching the Final Frontier*

A Simple Airframe for a Simple Flight Computer or Near Space Tracker.

*Learn how to turn a soft-sided insulated lunch box into a cost-effective airframe for your next mission.*



## Departments

<b>08</b>	<b>DEVELOPING PERSPECTIVES</b>	<b>74</b>	<b>NV WEBSTORE</b>
<b>24</b>	<b>NEW PRODUCTS</b>	<b>77</b>	<b>CLASSIFIEDS</b>
<b>31</b>	<b>SHOWCASE</b>	<b>78</b>	<b>TECH FORUM</b>
<b>66</b>	<b>ELECTRO-NET</b>	<b>80</b>	<b>AD INDEX</b>

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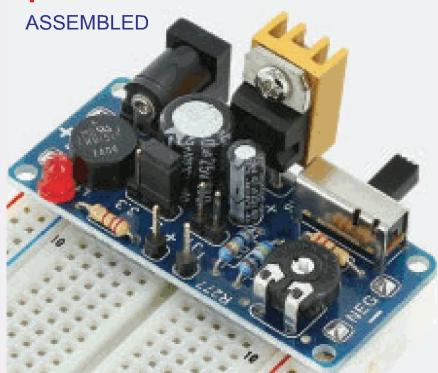
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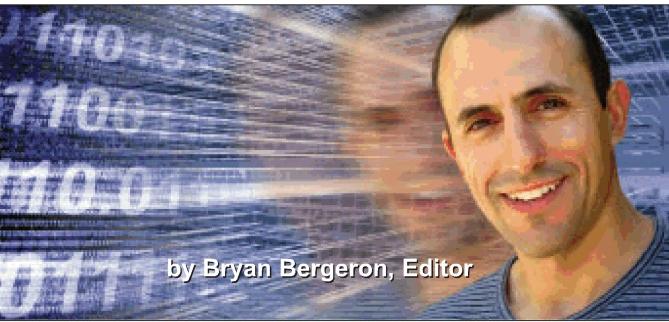
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# DEVELOPING PERSPECTIVES

by Bryan Bergeron, Editor

## Component Specifications: Trust or Verify?

It's easy to forget that no two components or devices are exactly alike. This is fairly obvious with common leaded resistors, given the tolerance marking is hard to miss — gold 5%, silver 10%, none 20% for four-band resistors. In other cases, it's less obvious.

For example, in working with batches of Arduino microcontrollers, I've noticed small but significant differences in the analog-to-digital conversion accuracy from one microcontroller to another. This may be due to differences in the ATmega chip but, more likely, it's due to

variations in the crystals or other external discrete components.

Often the exact or absolute value of a component isn't as important as having two or more components of the same value. For example, I just put together an MP3 player with the SparkFun MP3 player shield and their little TPA2005D1 audio amplifier breakout. The class D amplifier has a fully differential input that interfaces nicely with the output of the MP3 player. It also has the advantage of relative noise immunity.

However, I had to increase the gain of the amplifier for my application, and this meant using a pair of matching resistors to keep the performance optimized. So, I sat down with a few dozen 25K 5%

resistors and my lab-quality Fluke DMM and identified a matching set. I only wish it were this easy with other components.

Take vacuum tubes. I own several vacuum tube amps — one DIY and a couple vintage guitar amps. One guitar amp uses a matched pair of 6V6 output tubes, and the other a quad set or 'quartet' of 6L6 tubes.

In each case, the amplifier designs assume that the tubes are matched — in terms of transconductance — which is roughly the amount of amplification provided by a tube. It's actually the change in plate current divided by the corresponding change in grid voltage/plate voltage held constant.

The problem with tubes is that



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they're expensive, and there doesn't appear to be an industry standard for what "matched set" means. Moreover, matched sets command a 50%-100% premium over single tubes. As a point of reference, a single Groove Tubes 6L6 sells for less than \$20, while a quartet sells for \$140. So, I naturally look to online sources such as eBay for affordable sets.

Unfortunately, there's no way to know from mere visual inspection whether someone simply put four tubes in a box and called them matched. A few months ago, I snagged a 6L6 quartet on eBay for \$60. Quite a deal — until I plugged them in. The amp just didn't sound right.

My next purchase was an old but operable tube tester, shown in the accompanying photo. Given the age of the unit (a Hickok 6000A), absolute calibration probably isn't what it should be. However, because I'm looking for relative differences in tubes, calibration doesn't really matter.

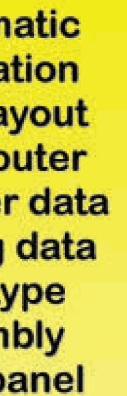
As I suspected, the tube tester showed marked differences in tube transconductance in the quartet. Since the meter purchase, I've amassed a small collection of bargain priced tubes and created my own matched sets. My amps are purring with delight.

Clearly — at least in the case of vacuum tubes — it pays to assume that "matched" is meaningless. I've encountered a similar 'lack of honesty' when it comes to "matched" speakers sold for DIY amplifier cabinets.

As analog electro-mechanical devices, speakers of the same make and model can vary significantly from one unit to the next. This becomes problematic if you want to combine two or four speakers in a cabinet while maintaining an impedance match for the amplifier output circuit.

The bottom line is that it often pays to verify component specifications, especially when you're paying a premium for supposedly premium components.

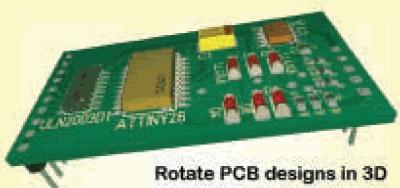
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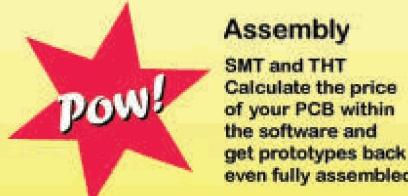


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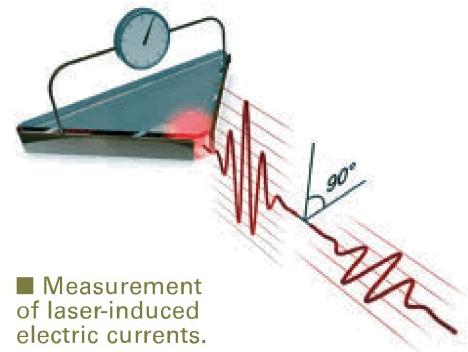
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# TECH KNOWLEDGEY 2013

■ BY JEFF ECKERT

EVENTS, ADVANCES, AND NEWS

## ADVANCED TECHNOLOGY



### NOT JUST A DIELECTRIC ANYMORE

As is widely known, materials can be herded into three groups according to their electrical properties: metals, dielectrics, and

semiconductors. Metals are highly electrically conductive, whereas dielectrics are nonconductors and tend to go up in smoke if you apply enough juice to them. Semiconductors are somewhere in the middle; they will conduct electricity, but only if kick started via the application of sufficient energy. For fairly obvious reasons, semiconductor materials have been used to fabricate transistor devices, as they can readily switch between conductive and nonconductive states. The problem is that today's best semiconductor components can't switch at rates exceeding a few gigahertz, which limits the operating speed of pretty much everything electronic.

However, a team of researchers from the Max-Planck-Institute of Quantum Physics, Georgia State University, and other institutions became curious about how certain dielectrics might respond to high power stimuli lasting just a very short time. To find out, they unsheathed a near-infrared laser capable of generating up to 10 billion volts for just a few quadrillionths of a second (i.e., femtoseconds). They equipped a silica-glass prism with gold electrodes spaced with a 50 nm gap, hit the prism with a few laser pulses, and — lo and behold — induced measurable current between the electrodes, indicating that the light field changed the material from an insulator to a conductor. Subsequent experimentation proved that the process is reversible, so the conclusion is that it is quite possible to use certain dielectric materials for signal processing, and at petahertz speeds — about 10,000 times faster than today's devices.

You shouldn't expect this discovery to turn into a new set of computer chips anytime soon, but as researchers put it, "Our work demonstrates how state-of-the-art photonic techniques may explore ways of pushing the frontiers of information processing," and, "We hope that these results provide motivation for other groups worldwide to join us in exploring and exploiting the potential wide-gap materials may offer for speeding up electronics." Two related papers have been published in the journal *Nature*, and are available at [www.nature.com](http://www.nature.com). ▲

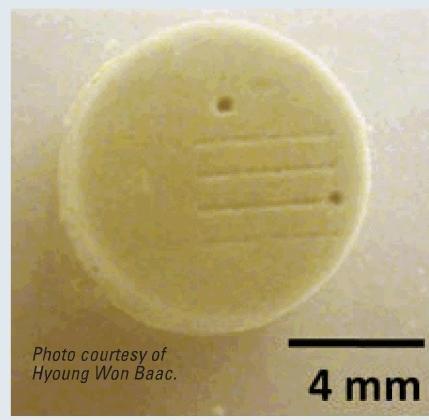
### SLICING WITH SOUND

We're all familiar with sounds that are so annoying that they "cut like a knife," but it now appears that the concept has moved beyond mere simile. Modern ultrasound techniques are commonly used to catch a glimpse of fetuses and other internal objects, and they can even be employed to zap kidney stones and prostate tumors. However, an engineering team at the University of Michigan ([www.umich.edu](http://www.umich.edu)) has developed a technique that could ultimately lead to an invisible ultrasonic knife for performing noninvasive surgery.

Existing focused ultrasound technology generates a focal spot that is typically a few centimeters in diameter, which does not provide enough precision for targeting "delicate vasculature, thin tissue layer, and cellular texture." So, the team has created a carbon nanotube-coated lens that converts light into sound and then focuses the sound waves with about 100 times better accuracy. They were able to concentrate high-amplitude waves into a 75 x 400 m speck that blasts and cuts with pressure rather than heat.

According to project leader Prof. Jay Guo, "We believe this could be used as an invisible knife for noninvasive surgery. Nothing pokes into your body, just the ultrasound beam. And it is so tightly focused, you can disrupt individual cells."

In separate experiments, they successfully detached a single ovarian cancer cell and blasted a 150 m hole in an artificial kidney stone. "This is just the beginning," added Guo. "This work opens a way to probe cells or tissues in much smaller scale." ▲



■ Artificial kidney stone with a 150 m opto-acoustically created hole.

Discuss this article in the Nuts & Volts forums at <http://forum.nutsvolts.com>.

## COMPUTERS AND NETWORKING

### TABLET TOO BIG TO SWALLOW?

One of the best features of a tablet computer is that it is compact and easy to carry around, so the new 20 in 4K tablet that Panasonic ([www.panasonic.com](http://www.panasonic.com)) introduced at this year's Consumer Electronics Show (CES) seems a bit counterintuitive — sort of like a six-passenger, two-ton smart car. Apparently the device — which the company says will be available sometime in the last half of this year — is designed as a commercial product primarily for "architects, graphic designers, and photographers" who can put the real estate to good use.

Its main features are the big IPS Alpha Panel display that sports 3840 x 2560 pixels (230 ppi) and can show more than 16 million colors. Plus, the user interface includes an electrostatic multi-touch panel (10 fingers) and an Anoto ([www.anoto.com](http://www.anoto.com)) high-res digital pen. Other specs for the Windows 8 based machine include a 1.8 GHz Core i5 processor, up to 16 GB of RAM, NVIDIA GeForce graphics, and an embedded HD 720P camera. It weighs in at a fairly hefty 5.3 lb (2.4 kg) and, as you might expect, doesn't offer



■ Panasonic's 20 in 4K tablet will be available the last half of 2013. ▲

much in the way of battery life: just two hours on a charge. With a 15:10 aspect ratio, it can display an A3 size paper (11.7 x 16.5 in, or 297 x 420 mm) in almost full size, making it useful for looking at things like newspapers and magazines. No MSRP was announced, but it's safe to say that it ain't gonna be cheap. ▲



■ Input up to three devices with Logitech's Easy-Switch keyboard.

### ONE KEYBOARD, THREE APPLES

A nifty new product aimed specifically at owners of multiple Apple devices is Logitech's ([www.logitech.com](http://www.logitech.com)) Bluetooth® Easy-Switch™ keyboard. You can use it simultaneously with up to three devices, such as your desktop, iPad, and iPhone, so you can go from word processing to taking notes to texting by just pressing a button. It includes the familiar Mac layout including the command, brightness, and Mission Control buttons, and the aluminum exterior provides a style match. In addition, it features backlit key illumination that automatically dims and brightens to match room lighting. You're looking at a \$99.99 MSRP. Logitech has also introduced a companion rechargeable trackpad that can be had for \$69.99. ▲

### WIRELESS STORAGE FOR EIGHT MOBILE DEVICES

Also performing with multiple cast members is the Wireless Plus mobile storage device from Seagate ([www.seagate.com](http://www.seagate.com)), which snagged a Best of Innovations Award at the 2013 CES. Using the mobile Seagate Media app, you can wirelessly transfer data to or from as many as eight Apple iOS, Android, or Kindle Fire devices. In fact, it will work with just about any Wi-Fi connected device, and you can even use it to show video, photos, music, and still graphics on a big screen TV via Apple Airplay, a DLNA device, or an app designed for Samsung Smart TVs and Blu-ray players. The 1 TB drive provides enough space for as many as 500 full length HD movies, and it comes with a removable SuperSpeed USB 3.0 adapter for quick file transfer. As of this writing, the street price is the same as the list: \$199.99. ▲



■ Seagate's Wireless Plus provides storage for up to eight mobile devices.



# CIRCUITS AND DEVICES



■ WinSystems' PPM-PS397-POE-1 is a DC/DC power supply module for PC/104-Plus compatible devices.

## NEW INDUSTRIAL POE SUPPLY

The concept of drawing power directly from an Ethernet connection isn't new or very complicated. You just string out some category 5 cable and attach a power over Internet (PoE) source device which allows you to send both data and up to 15.4W (IEEE 802.3af-2003) or 25.5W (IEEE 802.3at-2009) of power to a unit elsewhere in the network. This comes in handy in locations where other power sources are not readily accessible. Taking it a step further, WinSystems ([www.winsystems.com](http://www.winsystems.com)) has introduced what is said to be the first power supply module designed specifically to drive a PC/104-Plus compatible computer board stack. The PPM-PS397-POE-1 is a 25W unit that can be configured as either an endpoint or midspan device. It extracts power from a conventional twisted pair cat 5 cable in conformance with the 802.3af standard. DC power is extracted from the Ethernet cable to drive an onboard isolated DC/DC converter that generates DC output voltages of +5, +12, and -12 VDC, providing a regulated low ripple and low noise output to a PC/104-Plus connector. The PS397 measures only 90 x 96 mm, and operates over a range of -40°C to +85°C. The unit needs only convection cooling, so no fan is required. Interested parties are directed to contact the company for pricing specifics, but it is billed as "low cost." ▲

802.3af standard. DC power is extracted from the Ethernet cable to drive an onboard isolated DC/DC converter that generates DC output voltages of +5, +12, and -12 VDC, providing a regulated low ripple and low noise output to a PC/104-Plus connector. The PS397 measures only 90 x 96 mm, and operates over a range of -40°C to +85°C. The unit needs only convection cooling, so no fan is required. Interested parties are directed to contact the company for pricing specifics, but it is billed as "low cost." ▲

## NEVER LOSE ANYTHING AGAIN

If you're like most people, you lose a lot of things and end up spending far too much time poking around the house looking for them. Such items include car keys,



■ The Radar Screen app lets you find lost items via a smartphone.

wallets, remote controls, and Koozie cups with half finished bottles of beer. Well, help is here, thanks to the folks at Stick-N-Find Technologies ([www.sticknfind.com](http://www.sticknfind.com)). You just attach one of their small Bluetooth location sticky discs to virtually any item (glass, metal, painted surfaces, plastics, leather, and so on), and you can instantly locate it anywhere within about 100 ft (line of sight). The disc is only about the size of a quarter and weighs just 0.15 oz (4.5 g), so you can also use it to locate a family pet or a spouse who had a few too many and passed out in the shrubbery. It can even warn you if a subject moves out of range. Power comes from a CR2016 watch battery which is said to last about a year.

To locate the lost items, you need to run the Radar Screen app on an iOS device with Bluetooth 4.0 (iPhone 4s, iPhone 5, new iPad, New Touch, mini iPad) or an Android device that supports Bluetooth Low Energy and runs Android 4.1 or newer. Sadly, this means that a Stick-N-Find will not be useful for locating your lost smartphone.

The retail price ranges from \$49.95 for a twin pack to \$1,400 for a "company pack" of 100 stickers. Product delivery is not slated to begin until about the time you read this, but the company has already booked more than \$700,000 worth of preorders. Is there a demo vid? Of course. Just search for "stick-n-find" on YouTube. Now, if I can figure out how to attach one to my mind, I'll be in business. ▲

# INDUSTRY AND THE PROFESSION

## RIVAL FOR GPS?

When the LORAN system was shut down a couple years ago, few tears were shed as GPS provides greater accuracy and wider coverage. Still, GPS isn't so hot when you're inside a shopping mall or similar location. Now, an Australian company called Locata ([www.locatacorp.com](http://www.locatacorp.com)) is developing a ground-based system that projects radio signals over localized areas — and it even works indoors — as the signals arrive with about a million times the power of what your GPS receiver picks up. Even the US military (which invented the GPS system) is testing it out at New Mexico's White Sands Missile Range.

Reportedly, tests by the Air Force revealed that the system was accurate to within 18 cm (7 in) along any axis, and it should be possible to bring that down to 5 cm (2 in). Although it is unlikely to drive GPS into obsolescence, the technology could be married with it.

Leica Geosystems' ([www.leica-geosystems.com](http://www.leica-geosystems.com)) Jigsaw Positioning System employs both signal types, but their equipment is still the size of a briefcase and geared toward the mining industry. ▲



A pair of Locata transmit antennas overlook the White Sands Missile Range.

## EE JOB OUTLOOK IMPROVING

The electrical engineering profession took a beating during the recession, but *IEEE Spectrum* magazine has predicted a healthy revival in some areas. Hiring is up by about 10 percent overall, and big bucks are flowing into the power sector from both the federal government and industry. As a result, the utility industry hired about 120,000 new Bachelor's graduates last year with starting salaries averaging \$64,000. A master's will bring you around \$80,000, and a doctorate \$90,000, so maybe it's time to finish up that degree. NV

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# SPIN zone

■ BY JON MCPHALEN

ADVENTURES IN PROPELLER PROGRAMMING

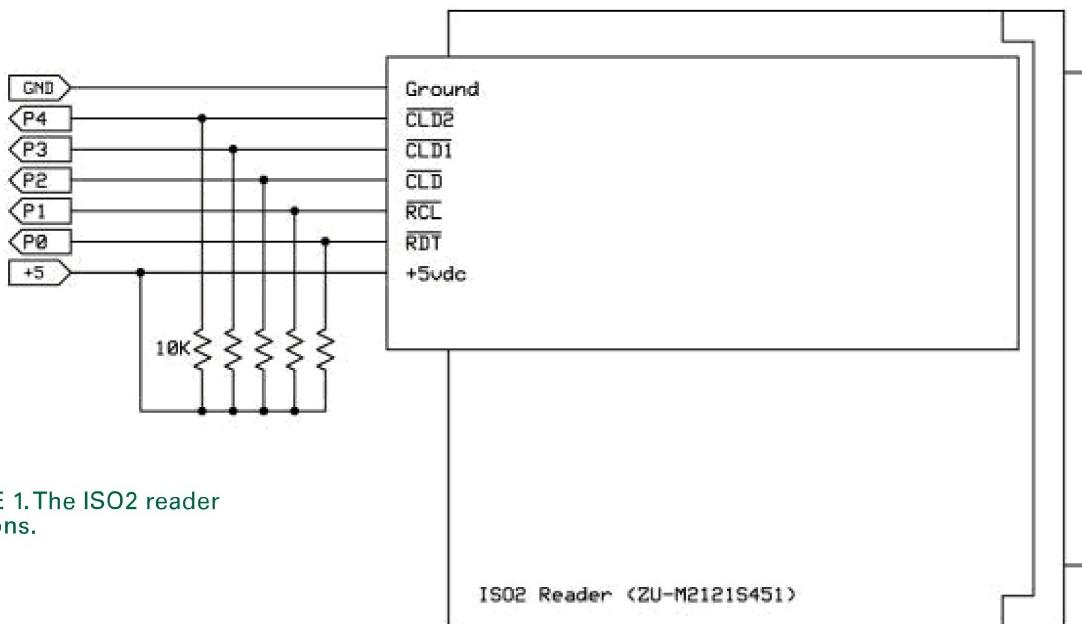
## PICK A CARD OR ... ABORT!!!

**Around Christmas time, I helped a friend with a reverse geocache project that he was building as a gift. Jeff hasn't had a lot of time with the Propeller yet, and I'm always happy to encourage anyone willing to give it a go. Part of the project involved "backdoor" access to the box in the event the number of attempts were exceeded by the user. We kept things simple — or so we thought — by using a magnetically-tripped reed switch inside the box. We did get it working, but the original switch was a bit of a problem.**

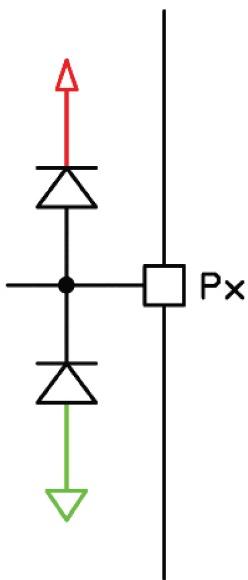
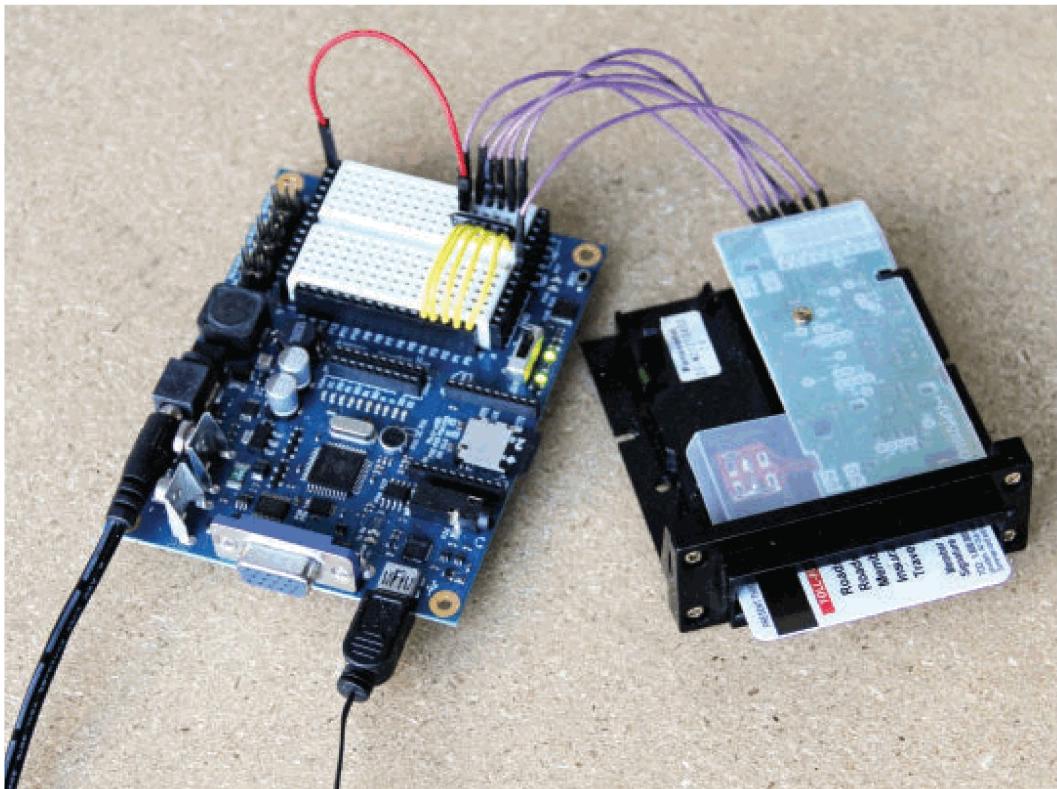
Not long after, I was looking through a parts drawer and came across a surplus magnetic card reader that I'd picked up at All Electronics. I immediately smiled, thinking this would have been a very cool "backdoor" access point for our project since we could have coded the box to open only for Jeff's credit card, while displaying all kinds of *"Thank you for the cash!"* messages if the user inserted their own card.

Long-time followers may remember that I wrote some code for a reader in SX/B about five years ago. The program worked just fine, but wasn't terribly sophisticated. With the resources of the Propeller and the ability to create object libraries, it makes good sense to connect the reader and write some new code.

**Figure 1** shows the basic connections to the Propeller; for my initial experiments, I connected to a



■ FIGURE 1. The ISO2 reader connections.

**FIGURE 3.** Pin diodes.**FIGURE 2.** Card reader with Prop-BoE.

Prop-BoE as in **Figure 2**. Note that the reader is powered by 5V and that all of the open-collector lines from the reader to the Propeller are pulled up through 10K (I used a SIP with five 10K resistors).

If you're new to the Propeller, you might be worried about connecting a 5V circuit to the I/O pins. It is quite safe to do — so long as we use a proper current-limiting resistor.

Have a look at **Figure 3**. Each Propeller I/O pin is protected by over-voltage diodes that — as we can find in the datasheet — have a forward voltage of 0.3V and a current limit of 500  $\mu$ A. Knowing this, we can do a little work with Ohm's Law to determine the proper size for a current limiter:

$$R = (5.0 - (3.3 + 0.3)) / 0.0005$$

Doing the math,  $R$  works out to 2.8K. That said, it's not a common value. For 5V interfacing, then, I use 3.3K (4.7K and 10K are fine, too, for low speed circuits like the card reader).

While working on the card reader code, I got a text message from my pal, Rick (another one of those amazing special effects wizards that I hang out with). He was wondering about the correct size of the current limiter for interfacing a 5V circuit to the Propeller.

I reminded him to remember 3.3: Use a 3.3K resistor to protect the 3.3V Propeller from a 5V circuit.

## CARD, PLEASE ...

The device we're using reads track 2 from ISO cards — like a credit card. This track is low density, and contains mostly numeric data and a few control characters. In my experiments with credit cards, I find that the credit card number is followed by the field separator character and additional data (usually the expiration date of the card).

Before we get to the code, let's look at the purpose of the reader's outputs:

/RDT	Inverted data
/RCL	Active-low clock
/CLD	Low while card is in motion
/CLD1	Low when card is inserted into reader
/CLD2	Goes low when card hits end stop

Understanding the purpose of each signal — and how data is written to the track — makes it fairly easy to design an algorithm for reading from the card. Data on track 2 is framed by special characters; there's the Start Sentinel at the beginning, then it is terminated by the End Sentinel:

1. Wait for card insertion.
2. Wait for card motion.
3. Look for Start Sentinel character.
4. Read characters into buffer, then quit when End Sentinel or End Stop is detected.

Steps 1 and 2 are easy because we only need to look at the states of those input pins. When we insert a card, the /CLD1 line will go low; it returns high when the card is withdrawn from the reader. When the card is inserted and in motion, the /CLD line will be low; if the card stops moving, this line will return high. Once we've started the read process, either of these lines going high indicates a problem and we should deal with it.

Step 3 is actually a bit interesting, given the way data is written to the card. As we start to push the card, we'll see active-low clock bits and the data line (/RDT) will remain high (0 bit). These leading zeroes give us the opportunity to sync up with the data bits. What we're going to do is create a moving window that is five bits wide, and exit the routine when the Start Sentinel character is detected. Have a look:

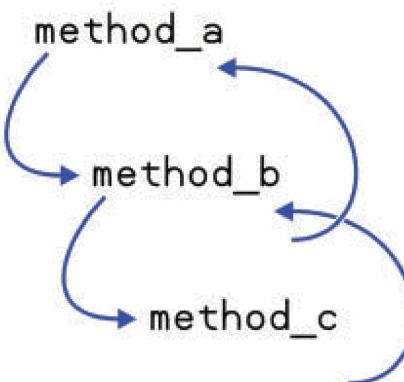
```
pri find_start_sentinel | ch

ch := 0
repeat
    repeat while (ina[crdclock] == 1)
        if (ina[crdmotion] == 1)
            abort BAD_SWIPE
        ch >>= 1
        ch |= (ina[crddata] ^ 1) << 4
        waitpeq(clkmask, clkmask, 0)
    if (ch == %0_1011)
        return 0
```

Keep in mind, of course, that we won't get to this point until we've called one of the reader's start methods; these simply define which pins do what, create a mask for the clock pin, and a timing value that we'll use later.

Okay ... heading in, we're going to clear the work variable **ch** (required as it's a local) and then drop into a **repeat** loop; this loop will run until the Start Sentinel character is detected in the stream or we abort due to an error.

At the top of the loop, we wait for the clock line to drop, and while waiting verify that the card motion has not stopped (/CLD goes high). Note that when it does, we exit the method with an **abort** code. Otherwise, when the clock line drops, we prep the work character for LSB first data by shifting it right one bit. Then, the data line is



■ FIGURE 4. Call and return.

sampled – XORed (^) with 1 to invert the bit – and finally shifted left to the bit 4 position (MSB) before being added to the work character. With the new bit in place, **waitpeq** holds the program until the clock line returns high.

At the end of the loop, we check for the Start Sentinel value of %0\_1011. If we don't have it, then the loop runs again. By following this process through a few cycles, we can see that we've created a five-bit sliding window on the data stream; on each clock, we shift bit 0 out and add a new bit 4.

## ABORT! ABORT! ABORT!

In most programs, a method simply returns to its caller with or without a value. In the above code, I want the method to return normally on finding the Start Sentinel, and abort the entire read process (that this is a part of) if the card stops moving.

When one method calls another, the return address for the calling method is pushed onto the stack along with any parameters required for the call. When the called method terminates, it pops the caller's address from the stack. **Figure 4** illustrates the normal call/return process with each nested method returning to its own caller.

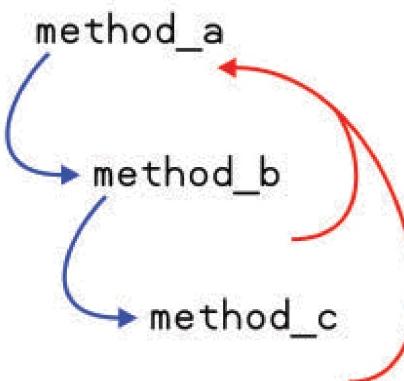
Consider this: How should we handle a serious problem that may be nested several calls deep? We could, of course, check the return values along the way, creating conditional code that handles errors. This could get very unwieldy and make our programs unnecessarily complicated – especially when a problem deep down the call stack needs to be dealt with by every method on the way back out.

Thankfully, Spin has a mechanism that saves the headache of trapping errors as we back out of a stack of nested calls; if we force the exit of a method using **abort** instead of **return**, the call stack will be popped all the way back to the topmost caller – we simply have to tell the code what this is. A typical method is called like this:

```
check := some_method
```

If we'd like to cleanly handle an error anywhere in a multi-level call using **abort**, we set a trap like this:

```
check := \some_method
```



■ FIGURE 5. Call with abort.

The backslash in front of the method name tells the compiler that an **abort** – no matter how far down the call stack – will force the program back to this point. This feature is extremely helpful in detecting and dealing with problems in nested calls. **Figure 5** illustrates the use of **abort** (red arrows); note that any **abort** in the nested calls goes directly back to the call using the abort trap.

There is no set rule for the values used by abort in reporting problems. For my projects, a value of zero or positive is normal; **abort** codes are reported as negative values.

Okay, then. Let's get back to building the elements for reading the track. After the Start Sentinel is found, we read characters into a buffer until the End Sentinel is detected or we hit the physical end stop (/CLD2 goes low). Characters are five bits; four bits are data, the fifth is the parity bit. Odd parity is used which means that the number of 1s in the character – including the parity bit – add up to an odd number:

```

pri read_char | ch, pcheck, idx

ch := 0
repeat 5
    repeat while (ina[crdclock] == 1)
        if (ina[crdmotion] == 1)
            if (ina[crdstop] == 1)
                abort BAD_SWIPE
            else
                return END_SENT
        ch >> 1
        ch |= ((ina[crddata] ^ 1) << 4)
        waitpeq(clkmask, clkmask, 0)

pcheck := %1_0000
repeat idx from 0 to 3
    if (ch & (1 << idx))
        pcheck ^= %1_0000
if ((ch & %1_0000) <> pcheck)
    abort BAD_PARITY

return Track2[ch & $F]

```

The first half of the **read\_char** method is identical to the **find\_start\_sentinel** method in that we capture five inverted bits on the falling edge of the clock line. In this case, though, when the motion input indicates the card has stopped we check the physical limit input. If the physical end is detected, then we return the End Sentinel character.

For most characters, we need to check the parity bit before returning – or possibly aborting – the read on a parity error. We start by presetting a parity check variable and then looping through the data bits (0–3) of the character. If we find a bit is set (1), then the parity check

bit is XORed with 1 to invert it. After the loop, compare the calculated parity bit with what we read from the track (bit 4); if they match, we have a good character that is converted to ASCII using a simple table, and is then returned.

You probably noticed that the **find\_start\_sentinel** and **read\_char** methods are **private**; this means they cannot be called directly from the parent object. These methods are called from **read\_card** which puts everything together to read the track 2 data:

```

pub read_card(timeout) | t, idx, ch

if (!card_inserted)
    abort NO_CARD

bytefill(@buf, 0, BUF_SIZE)

t := cnt
repeat
    waitcnt(t += ms1tix)
    timeout -= 1
    if (ina[crdmotion] == 0)
        quit
    elseif (timeout == 0)
        abort BAD_INSERT
    elseif (ina[crddetect] == 1)
        abort NO_CARD

find_start_sentinel

idx := 0
repeat BUF_SIZE
    if ((ch := read_char) <> END_SENT)
        buf[idx++] := ch
    else
        buf[idx] := 0
        quit

return @buf

```

In the normal course of a program, we will wait for a card insertion and then call the **read\_card** method to use the abort trap, of course. If all goes well, the return value

## RESOURCES

**JON "JONNYMAC" MCPHALEN**  
[jon@jonnycphalen.com](mailto:jon@jonnycphalen.com)

**PARALLAX, INC.**  
**Propeller chips and programming tools**  
[www.parallax.com](http://www.parallax.com)

## PARTS LIST

ITEM	DESCRIPTION	SOURCE
ISO2 Card Reader	#ZU-M2121S451	www.mecu.com
Propeller BoE	#32900	www.parallax.com
10K SIP 5x + COM	#264-10K-RC	www.mouser.com
M-F Jumper Wires	#1701	www.pololu.com

will be the hub address of the track buffer; this will hold ASCII characters — mostly numbers, but we could have the “=” field separator mixed in, as well.

First things first: If the method is called with no card inserted, we abort — we cannot read a card that isn’t inserted into the reader! If a card is present, the buffer is cleared and the code will wait for the card to start moving. Note that the method requires a timeout period (specified) in milliseconds; this is designed to allow the user to align the card in the reader before pushing it in to read.

The timeout feature is handled in a synchronized loop that runs every millisecond. If motion is detected (/CLD is low), we can quit the loop and continue reading the track. If there is no motion or the card is extracted during the timeout period, we exit with an **abort** code.

Once the card is moving, we look for the Start Sentinel and then drop into a loop that moves the characters read from the track into a buffer; that loop terminates when the End Sentinel character is detected. Finally, a good read causes the method to return the address of the track buffer.

Now ... look at this method again and think about it in context of error handling. Note that after calling **find\_start\_sentinel**, we don’t have to do anything special to detect a problem. In fact, we don’t do anything here — this is the beauty of using **abort**. The same holds true when calling **read\_char**; it will not, in fact, ever return a bad character. If there is a problem in **read\_char**, we will safely escape all the way back to the original caller using **abort**. Again, note how neat and tidy this method is despite all the error handling we’ve built into the process.

## SHOW ME YOUR CARDS!

Okay, then. Let’s put it to work in a simple demo program:

```
pub main | check

term.start(RX1, TX1, %0000, 115_200)
iso2.start(RDT)

pause(10)
```

```
term.tx(CLIENT)
term.str(string("ISO2 Card Reader",
CR, CR))

repeat
    term.str(string("Waiting...", CR))

repeat until iso2.card_inserted
check := \iso2.read_card(1000)

if (check => 0)
    term.str(@Arrow)
    term.str(check)
    term.tx(CR)
else
    term.str(@Arrow)
    term.str(iso2.errstr(check))
    term.tx(CR)

repeat while iso2.card_inserted
term.tx(CR)
```

After starting a serial object (for terminal output) and the card reader, we drop into a loop that waits for the card to be inserted before calling the **read\_card** method. Note that the method is called using the abort trap () and a one second timeout, and that we are expecting a positive value in **check** when all is well.

When we have a good read, the contents of the track buffer are printed. Otherwise, we should indicate what went wrong with the read. The card reader object has a method called **errstr** that will convert the known error codes into a string pointer that can be printed:

```
pub errstr(e)

case e
    NO_CARD:
        return string("No card.")

    BAD_INSERT:
        return string("Bad insertion.")

    BAD_SWIPE:
        return string("Bad swipe.")

    BAD_PARITY:
        return string("Parity error.")

    other:
        return string("?)")
```

With everything working, I did a bit of Googling and found algorithms for identifying and validating credit cards. The latter is handled with a method that employs

the Luhn algorithm; this is a means of checking a series of digits to determine if it's a valid credit card number. Note that it will only tell us if the string of digits *could* be a credit card, not that it actually is one. It's not secure, and it's not meant to be — it's simply a top-level check.

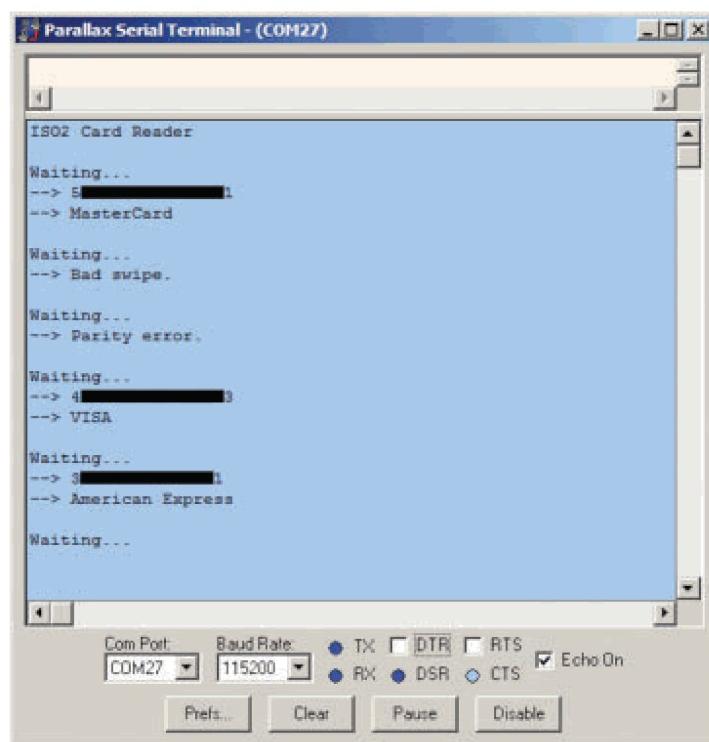
**Figure 6** shows the (redacted) output from the fancy version of the program. You'll forgive me for not wanting to print my credit card numbers!

While testing this version (included in the article downloads), I swiped my AAA membership card and it is reported as a VISA. Of course, it's not, and if there is a valid VISA card with those same digits it will also include a security code which helps to prevent unauthorized purchases.

So, once again, we've breathed new life into an inexpensive piece of surplus hardware and — I hope — learned how we can use **abort** to create programs with robust error handling.

Until next time, keep spinning and winning with the Propeller! **NV**

■ FIGURE 6. Reader display.



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# QUESTIONS & ANSWERS

WITH RUSSELL KINCAID

In this column, Russ answers questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. Send all questions and comments to: Q&A@nutsvolts.com

Be sure to check out the transistor modeling tutorial on pages 22-23.

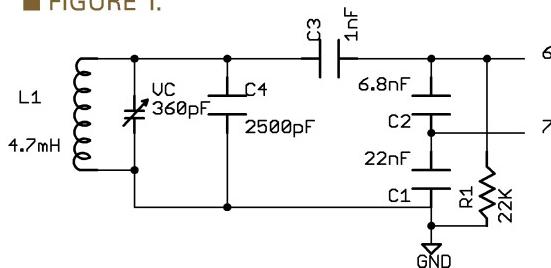
## TUNED CIRCUIT VALUES

**Q** Can you please give me the values I need for the tank circuit in **Figure 1**? This is in conjunction with an NE602 or SA612. Pins 6 and 7 are internal transistors of the mixer. The frequency needs to be in between 38 to 40 kHz. I need values for C1-C4 and L1, plus the variable capacitor which adjusts the frequency between 38 to 40 kHz.

— Craig Sellen

**A** I added R1 to give a better waveform, but the circuit works without it. I arrived at the values by trial and error, using SwitcherCad from Linear Technology. Other configurations could be used but this one resulted in an easily obtained variable capacitor. I used a 2N3904 transistor for simulation.

■ FIGURE 1.



## SOLAR POWER FOR MICROCONTROLLER

**O** I want to power my digital clock circuit (which has a PIC16F877A) from a battery that is charged from a solar array. I have been using a 12V SLA battery and 12V solar array. The circuit operates from a 12V to 5V DC supply and draws 800 to 1,200 mA. How can I do that circuit?

— Selahattin ŞADOGLU

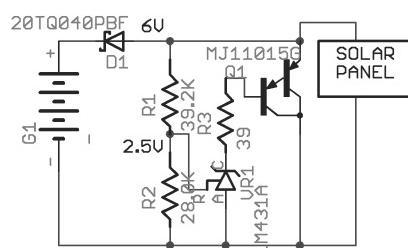
**A** The 16F877A operates from four volts to 5.5 volts, so you could use four NiCad cells for power. The NiCad cell can reach 1.4 volts under charge, so a regulator is needed to prevent exceeding the voltage rating of the micro. The solar panel needs to supply the current to the circuit plus a charging current. As an example, the Harbor Freight solar panel number 96418 provides 1.2 amps in bright sun. That is enough to operate the circuit, but not enough to charge the battery. So, you would need two panels in parallel. If the

panels track the sun, it will be most efficient; if they are fixed, you can only count on four hours of charging time and only on sunny days. Therefore, the battery should have an amp-hour rating of 50 Ah or more. In order to recover 50 Ah in four hours, the charge rate needs to be 12.5 amps;

that means 10 panels in parallel.

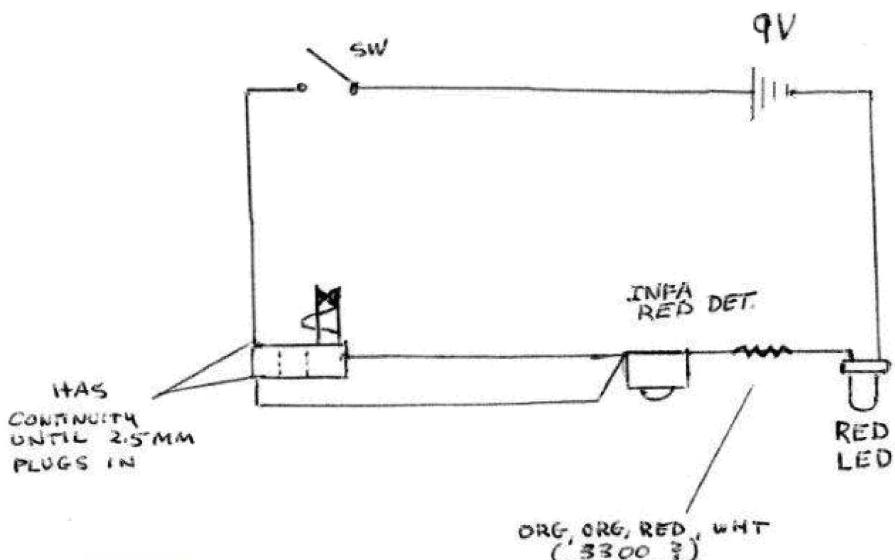
The shunt regulator (**Figure 2**) sends the excess current to the negative terminal of the solar panel and maintains the voltage at the cathode at six volts. The diode prevents the battery from discharging through the regulator and maintains the battery voltage at approximately 5.5 volts. The power dissipation is 75 watts when the battery is fully charged in bright sun. To limit the temperature rise to 100 degrees C, the heatsink must be rated  $100/75 = 1.33$  degrees C/watt. The Wakefield 641-A heatsink is rated at 0.9 degrees C/watt when cooled with a fan.

■ FIGURE 2.



## TOUCH SWITCH

**O** Years ago (and maybe still today), you could purchase a lamp with a metal base that included a touch/dimmer control. Later, I found that you could purchase these three-wire modules and wire them in your own light fixture with a metal base and have the touch/dimmer control. Well,



■ FIGURE 3.

as CFLs became popular — and now LEDs — those old touch/dimmer modules don't work so well. I cannot seem to find a similar module that is just a touch on/touch off, rather than going through the dimming process. Is anybody familiar with these modules? How hard would it be to modify it just to switch on and off? Or, is there a circuit handy that one can build (using the 120V) for the lamp to power it?

— Terry Arnall

**A**I don't know how these touch controls work, but a Google search turned up **TouchandGlow.com** which has multiple products in this line including plug-in, wireless, and do-it-yourself modules. Check out [www.touchandglow.com/product-p/diy-l4.htm](http://www.touchandglow.com/product-p/diy-l4.htm).

## REMOTE TESTER PROBLEM

**O** Could you give me a clue here to my remote infrared checker that I built years ago? I don't know now who published the schematic

(Figure 3). It was working until I replaced the battery, and then it quit. I replaced the 2.5 mm plug, the infrared detector, and the red LED. The 2.5 mm socket has continuity to the detector until you plug it in, then it bypasses to the jumper wire. I just used an off-the-shelf detector and standard LED in replacement. I don't know if the originals were special.

— Hank Redding

**A** What did you use for the infrared sensor? I suggest you check the polarity of the LED, sensor, and battery. If you monitor the voltage drop across the sensor while operating a known good remote, that will tell you if it is working. Please let me know what you find.

Hank has since reported that the LED was connected in reverse; it works now, but weakly because the detector sensitivity is low. **NV**

**Remember!**  
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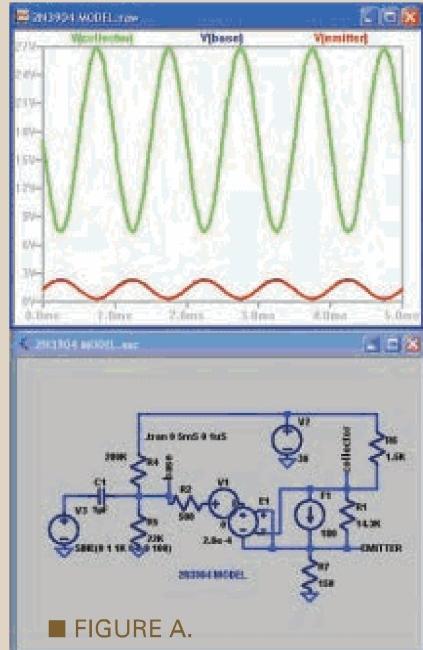
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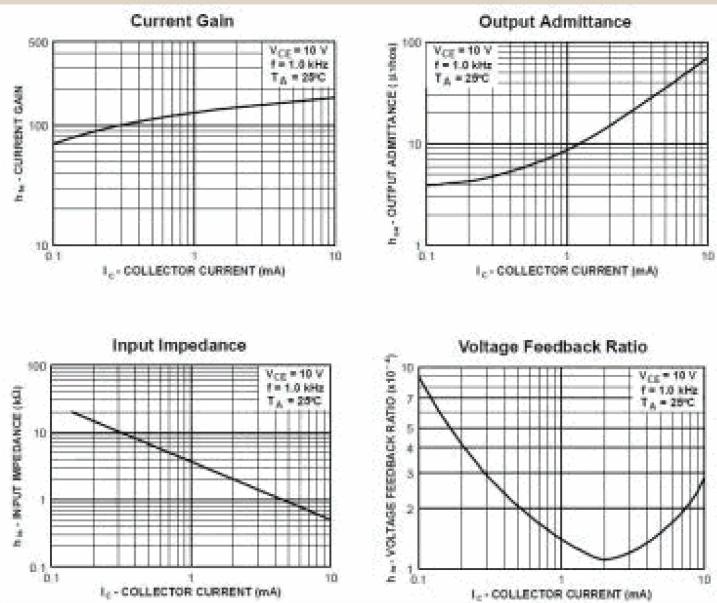
## TRANSISTOR MODELING

As a mini tutorial, I want to show how to make a bipolar transistor model for when you can't find a SPICE model. The hybrid model that I'll describe is



■ FIGURE A.

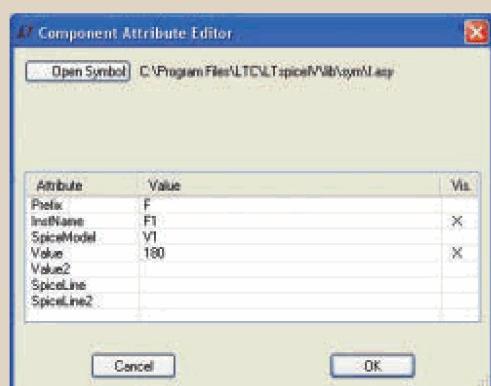
■ FIGURE B.



valid only under the conditions given here, whereas the SPICE model will be valid under all conditions. I chose the 2N3904 because there is a SPICE model for comparison and I have the datasheet.

The model is shown in **Figure A**. I chose R4 and R5 (not part of the model) to give a collector current around 10 mA, and modeled around that parameter.

The input impedance is  $R_2$  and is called  $h_{ie}$  on the datasheet; see **Figure B**. At  $I_c = 10$  mA,  $h_{ie} = .5\text{K}$ . The voltage source,  $V_1$ , is set to zero volts because its only function is to measure the base current for the current-controlled source,  $F_1$ . You will find the current-controlled source in



■ FIGURE C.

SwitcherCad designated as f; you will have to tell it (right-click on the symbol) the value which is  $h_{fe}$  at 10 mA, and the voltage source that provides the reference current. Take a look at **Figure C**. I read  $h_{fe}$  to be 180. The output admittance is  $h_{oe}$  which I read to be 70  $\mu$ ohm. The inverse is a resistance .0143 megohms = 14.3K. The voltage controlled source, E1, models internal feedback in the transistor. The effect is small, so you can

leave it out if you don't have the data. The value is  $h_{re}$ . I assumed the feedback is 180 phase, so I swapped the control wires. That completes the model.

I chose a load resistor, R6, to give 15 volts drop at 10 mA and  $R7 = 150$  ohms for a gain of 10. The input is one volt peak and the output is close to 10 volts peak (20 volts peak to peak). The comparison circuit (**Figure D**) using the

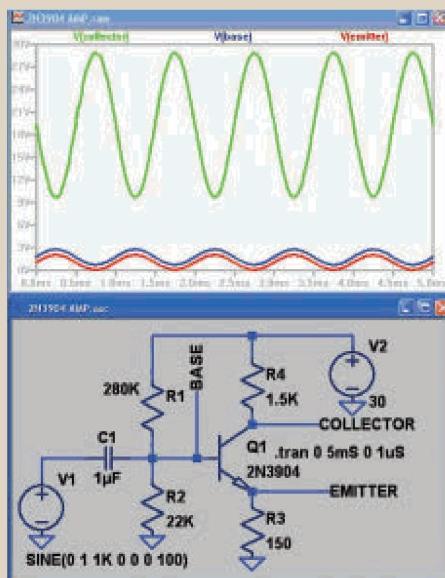
SPICE model stacks up favorably with the hybrid model.

If you don't have a datasheet but you have the transistor, you can calculate and measure the parameters.

For input impedance, use:  $h_{ie} = .026 * h_{fe} / I_e$  where  $I_e = I_b + I_c$  and  $h_{fe} = I_c / I_b$ . For output impedance, set the collector current at the desired value, then vary the collector supply voltage and measure the collector voltage and

current. The change in collector voltage ( $\Delta V$ ) divided by the change in collector current ( $\Delta I_c$ ) is the output resistance. I don't know how to measure  $h_{re}$  so leave that out.

■ FIGURE D.



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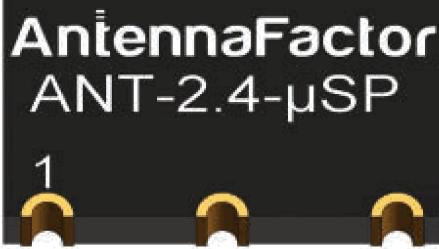
For complete information, visit [HakkoUSA.com/NutsVolts](http://HakkoUSA.com/NutsVolts)

# NEW PRODUCTS

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## MICROSPLATCH ANTENNA BREAKS CHIP BARRIER

The MicroSplatch™ antenna from Linx Technologies is a new alternative for those wishing to avoid



high costs, long lead times, or limited frequency choices of chip antennas. The MicroSplatch antenna represents a groundbreaking advance in Linx' reflow-compatible planar antennas.

Using advanced simulation tools, Linx designed the MicroSplatch with performance similar to the standard Splatch antenna, but this new version only uses one third of the critical board space. The small size and low cost makes the MicroSplatch an excellent choice for handheld devices such as remote controls and small data transmission systems.

Adding the MicroSplatch to a design is simple. The only things needed are a footprint for the antenna and associated proximity ground plane. The MicroSplatch is available in the 403 MHz, 418 MHz, 433 MHz, 868 MHz, 916 MHz, and 2.4 GHz bands. Custom designs within the 400 MHz-3 GHz range are available.

For more information, contact:  
**Linx Technologies**  
Web: [www.linxtechnologies.com](http://www.linxtechnologies.com)



## NEXT-GENERATION TEMP/RH DATA LOGGERS

Onset has announced the HOBO UX100 Series – the company's next-generation family of data loggers for tracking temperature and relative humidity in indoor environments.

Starting at just \$75, HOBO UX100 Series loggers deliver high accuracy, large measurement capacity, and more LCD display features to make environmental data collection faster and easier.

The matchbox-sized data loggers quickly and easily collect indoor environmental data for a broad range of applications. This includes monitoring occupant comfort in office buildings, tracking food storage conditions in warehouses, logging temperature trends in server rooms,

and measuring humidity levels in museums.

UX100 loggers also feature start and stop pushbuttons, and rare earth magnet, strap, and command-strip mounting options enabling faster deployment and greater mounting flexibility and reliability.

Once data has been recorded with the data loggers, it can be viewed in graph form and analyzed using Onset's HOBOware® Pro software. Time-saving tools allow users to batch-configure and read out hundreds of loggers in a fraction of the time it would take with previous generations. Additionally, the software features a Bulk Export tool that allows users to export data files to text format for use in spreadsheets; it is available in English, French, Spanish, Portuguese, and German languages.

This series includes five models, including temperature-only loggers with integrated sensors to temperature/RH and thermocouple loggers with external probes. Prices range from \$75-\$189.

For more information, contact:  
**Onset**  
Web: [www.onsetcomp.com](http://www.onsetcomp.com)

## BLUETOOTH MODULE FOR STREAMING AUDIO

Microchip Technology, Inc., has announced the expansion of its wireless product portfolio with a

certified Bluetooth® audio module that supports audio for voice and music.

The RN52 module provides extremely low power consumption in a small, surface-mount form factor, and includes standard Bluetooth audio and data profiles for all smartphone platforms. These features

## TRANSPARENT PROTO-BOARDS

Global Specialties has introduced two new and unique transparent Proto-Boards® — models PB-242T and PB-326T.

These two new transparent models have ABS plastic sockets with phosphor-bronze contacts that are mounted on metal back plates for added durability. The transparent ABS plastic sockets are perfect for educational applications because they allow students and designers to clearly view circuit connections from the front of the Proto-Board. Each of these new models offer plastic feet, color-coded and marked contact areas, and four binding posts (three red and one black).

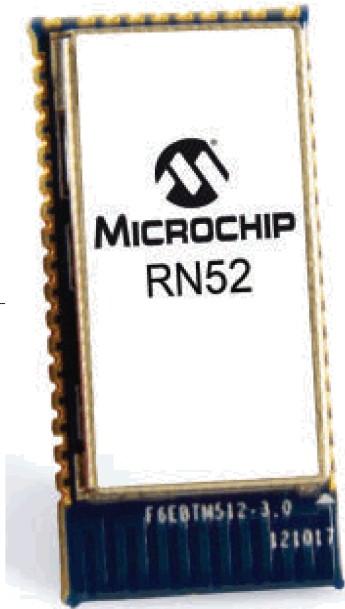
The Proto-Boards can be used to design test fixtures, perform lab experiments, and other areas of custom electronic design applications. The new transparent model PB-242T with 2390 tie points lists for \$65; the PB-326T with 3,220 tie points lists for \$89.



## MICROPROCESSOR DESIGN TRAINER

Also available from Global Specialties is the DL-030 Microprocessor Design Trainer. The DL-030 utilizes an FPGA chip allowing a user to implement a fully functioning microcontroller in minutes. The DL-030 is a complete and ruggedly packed trainer that will provide a solid learning platform for individuals and classroom students.

With the DL-030, you can create and implement your first design in as little as one hour. Features include:



help designers add high quality wireless audio — combined with data capabilities — in a broad range of applications such as wireless stereo speakers, headphones, automotive hands-free, medical devices, and computer accessories.

The RN52's embedded Bluetooth stack includes the popular SPP, A2DP, HFP/HSP, and AVRCP profiles, along with the iAP for use with an

- Altera Cyclone® III FPGA.
- Altera Nios® II embedded processor.
- Software CD with designing/implementing tools.
- A 137 page lab manual by university professor, Enoch Hwang, PhD.
- iPad version of the lab manual available on iTunes.
- Eleven hands-on labs correlated to any textbook for microprocessor design training.
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- Sixteen slide switches and three pushbutton switches.
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- Perform experiments using standard TTL logic.
- Four each, regulated 5V power (Vcc) and ground (GND) points.
- Eight input/output connection sockets.
- High quality machined sockets for input and output interconnections.
- The DL-030 can implement all of the experiments and circuits of the DL-010 and DL-020 trainers plus more.

For more information, contact:  
**Global Specialties**  
Web: [www.globalspecialties.com](http://www.globalspecialties.com)

iPhone® or iPod®. Additionally, the RN52 supports a variety of audio codecs such as SBC, aptX®, AAC, and MP3.

A Bluetooth audio evaluation kit is available for \$169.95.

For more information, contact:  
**Microchip**  
Web: [www.microchip.com](http://www.microchip.com)

## HARMONIC OCTAVE GENERATOR/POLYPHONIC SYNTHESIZER

**E**lectro-Harmonix has introduced their new H.O.G.2. This second generation harmonic octave generator/guitar synthesizer builds upon the legacy of their critically acclaimed H.O.G.

The H.O.G.2 packs all the polyphonic power of the original unit, but based on feedback from users and new developments in technology, the new H.O.G.2 offers a number of enhancements and upgrades that include:

- Improved algorithms for each synthesized voice and for freeze capture.
- Full MIDI control.
- Presets can be loaded and stored via MIDI.

- A new, optional foot controller that allows the user to store and load up to 100 presets.
- Now compatible with the industry standard nine volt DC/200 mA center negative power supply.

The polyphonic H.O.G.2 still offers glitch-free tracking and complete control of up to 10 interval pitches without the need for special pickups. It provides a freeze mode with glissando, independent attack and decay controls, and dedicated resonant filtering with a sweepable frequency control. An Expression mode permits  $\pm 1$  octave bends, one step pitch bends, plus control over freeze + gliss, freeze + volume, wah wah, and filter frequency.

As mentioned, a new H.O.G.2 foot controller is also available. It



allows users to recall up to 100 presets in the H.O.G.2 main unit. Presets 0 through 11 are factory presets specially designed to give the user a wide array of sounds available from the H.O.G.2.

The H.O.G.2 carries a list price of \$635. The H.O.G. foot controller is priced at \$181.

For more information, contact:  
**Electro-Harmonix**  
Web: [www.ehx.com](http://www.ehx.com)

## NEW BOARD FOR TIMSP430F5172

**S**chmartBoard has expanded its product offering with a new development board to support users of Texas Instruments microcontrollers. These boards use their "EZ" soldering technology to assure fast, easy, and flawless soldering.

The MSP430F51x2 series are microcontroller configurations with two 16-bit high resolution timers, universal serial communication interfaces (USCI\_A0 and USCI\_B0), a 32-bit hardware multiplier, a high performance 10-bit analog-to-digital (A/D) converter, on-chip comparator, three-channel DMA, 5V tolerant I/Os, and up to 29 I/O pins. The MSP430F51x1 series are microcontroller configurations with two 16-bit high resolution timers, universal serial communication interfaces (USCI\_A0 and USCI\_B0), a 32-bit hardware multiplier, on-chip comparator, three-channel DMA, 5V tolerant I/Os, and up to 29 I/O pins.

Typical applications for these devices include analog and digital sensor systems, LED lighting, digital power supply, motor control, remote controls, thermostats, digital timers, handheld meters, etc.

The board is priced at \$35.

For more information, contact:  
**SchmartBoard**  
Web: [www.schmartboard.com](http://www.schmartboard.com)



## CHANNEL MOUNT SERVO POWER GEARBOXES

The first in a new line of gearbox products to be released by ServoCity this year are the new channel mount servo power gearboxes. By incorporating threaded side mounts, users can easily attach these servo gearboxes to numerous ServoCity products, making it easier to incorporate a servo power gearbox into a custom pan & tilt, mechanical device, or robotic structure.



## SOLAR PANEL AND CONTROLLER KIT FOR DORMANT BATTERIES

Goal Zero is now offering their Guardian charge controller kit to protect and extend RV, ATV, boat, and other seasonal 12V vehicle battery life during the offseason. The Guardian charge controller passes a charge from the accompanying Goal Zero solar panel to ensure the battery is not over- or under-charged, and is ready to go on the first day it's put back in use.

The Guardian kit is plug and play; the Nomad 13 or Boulder 15 solar panel simply plugs into one of the Guardian charge controller's two inputs. The included alligator clips plug into the Guardian's output port and then attach to the corresponding

Full metal gears (32 pitch) provide strength and durability. By utilizing digital servo technology, the user is able to tailor the gearbox to fit various performance parameters. The .770" pattern on the output hub gives nearly unlimited attachment possibilities. You can select from 90°, 180°, 360°, or continuous rotation.

## 90° ALUMINUM TUBE CLAMPS

Also from ServoCity are new tube clamps for attaching two pieces of shafting or tubing at a 90° angle.

Constructed from 6061-T6 aluminum for superior strength, the clamps don't easily flex or bow.

The 5/8" bore 90° tube clamp is perfect for builds that require smaller tubing in tight spaces. The 5/8" bore version comes with two 6-32 x 3/8" socket head screws. The larger 90° tube clamp with a 1" bore is designed for bigger projects that require 1" tubing or shafting. The 1" bore clamp also has two additional 6-32 thru holes at the



bend that provide an additional mounting point to other components. The larger tube clamp includes two 6-32 x 1/2" socket head screws.

The 5/8" bore tube clamp is \$7.99; the 1" bore tube clamp is \$8.99.

For more information, contact:  
**ServoCity**  
Web: [www.servocity.com](http://www.servocity.com)

red and black terminals on the battery.

The charge controller automatically turns off and on to maintain the battery at the optimum level. The Guardian also tapers the voltage according to the battery's condition and recharging needs to ensure a healthy battery pack and prevent over-charging. Guardian owners can daisychain multiple solar panels together for a faster charge.

The Guardian charge controller kit is available for \$249.99 with the foldable Nomad 13 solar panel, or for \$209.99 with the Boulder 15 solar panel.

For more information, contact:  
**Goal Zero**  
Web: [www.goalzero.com](http://www.goalzero.com)



## FLASH DRIVE SIZED RF SIGNAL GENERATOR

Saelig Company, Inc. announces the availability of the TEG4000-1 – a laboratory quality, synthesized 200 to 4,000 MHz RF signal source. The TEG4000-1 is the smallest USB microwave synthesized source available and is priced significantly below other competitive bench-top offerings. This handy RF source can be swept in step sizes as low as 1 kHz between any two frequencies in its specified range.

The TEG4000-1 offers +1 dBm output from its SMA connector, and is controlled and set via the supplied PC software. Its easy-to-use graphical interface offers both numeric entry or slider controls. A significant feature of

the device is that it can be preset to output a specific frequency when PC-connected. In the field, it then becomes a high quality preset frequency source when 5V is applied to its USB connector, without needing a PC connection.

The TEG4000-1 contains a stable, high quality internal 2 ppm 10 MHz crystal reference with -100 dBc/Hz phase noise at 100 kHz offset. Power consumption is 150 mA at 5V. The unit also contains 0.5 GB of Flash memory used for installation files, test data, and other supporting documentation. Drivers, utilities, and documentation are stored on the signal source itself. The API drivers provided are compatible with, C++, C#, VB.NET, Agilent VEE, LabVIEW, and other development tools.

Housed in a tiny case the size of a typical Flash drive, the TEG4000-1



weighs 1 oz and can be carried in a pocket or briefcase.

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## PROGRAMMABLE DUAL RANGE DC POWER SUPPLIES

B&K Precision has announced its new 9170/9180 series of programmable dual range power supplies. These nine models provide clean and precise power up to 210W in various configurations of voltage as high as 600V and current as high as 20A. Each model offers two ranges of voltage and current output, along with modular interface slots for remote interface configurability.

Arriving in rack-mountable single and dual output model configurations, these DC power supplies are suitable for bench and ATE applications in design engineering labs and electronics manufacturing.

Models in the 9170/9180 series feature line and load regulation less than 0.01% + 1 mV, 0.01% + 250  $\mu$ A, ripple and noise less than 0.35 mVrms, a full numerical keypad with vertical and horizontal cursors for direct entry of voltage and current values, front and rear panel output terminals, remote sense terminals, and a standard SCPI compliant USB interface for remote control.

Unique to the 9170/9180 series is its modular interface design and special LED test modes. Users have the option to choose from up to four different types of interface cards which include: LAN and GPIB, digital I/O and analog control, RS-485, or RS-232. These cards can be installed at any time when needed into either of the two modular interface card slots on the power supply's rear panel. LED test modes can be used to minimize inrush current for safe testing of LEDs.

Other features include programmable voltage and current slew rates, list mode for executing programmed test sequences, and ability to store and recall up to 10 different power settings. Models with



the optional LAN/GPIB interface card installed provide a built-in web server interface for remote control via a Java-enabled web browser. Both application software and LabVIEW

drivers are available for users to download from B&K Precision's website.

*Continued on page 73*

**EARN MORE MONEY  
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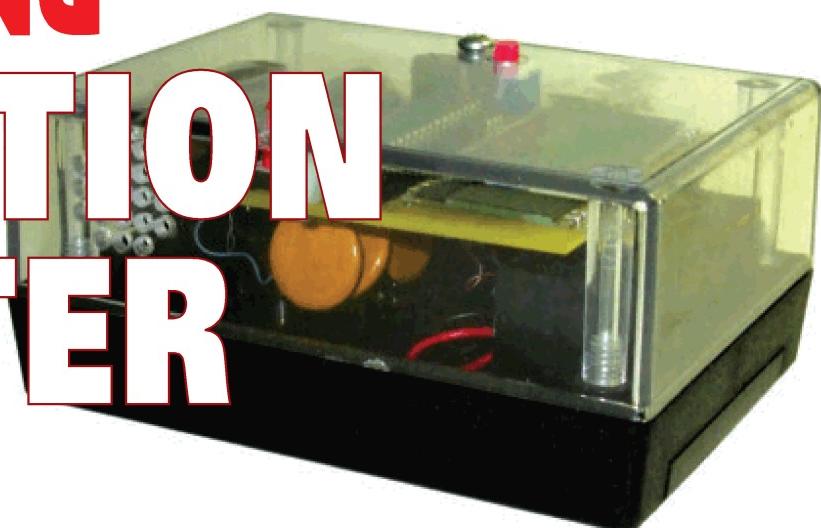
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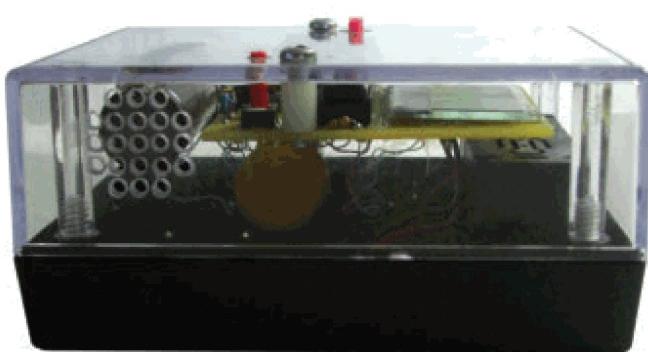
# A RECORDING RADIATION COUNTER



By Ron Newton

**In 1990, my wife and I had the great opportunity to visit and live in Russia. We stayed with a family in Kiev located in the Ukraine. The Chernobyl disaster had occurred four years earlier and they were still washing down the streets daily. In those days, it was illegal in Russia for the people to possess a Geiger counter, so they had to rely on local authorities.**

Fedor, our host (also a Russian physicist,) was most concerned about his grandchildren and the effects of the radiation. Rumors were still flying after four years, and no one really knew the facts. Milk and produce were their main concern. He asked me if I could provide him with a Geiger counter. When I returned to the states, I decided to put one together and sent it to him. The radiation levels he found were of concern, especially in tree fruit.



I recently re-examined my schematic of this unit. I added a microprocessor for control and a new display. I recommend an LND 712 Geiger tube which appears to be the gold standard of portable counters. It is capable of

measuring alpha, beta, and gamma particles.

If you don't want to spend a lot of money on a Geiger tube, you can find some on eBay for under \$5. (Keep in mind that you may need to adjust the high voltage for the tube. This is discussed further in the sidebar on Hints and Tips on page 38.)

This device would be a great project for high school and university students. It is simple to assemble and teaches a number of techniques.

The unit detects and displays levels of radiation, and can detect and display dosage levels as low as one micro-roentgen/hr to many micro-roentgens/hr. It can also detect radon (which emits alpha particles).

This unit has an advantage over other devices because it has an output for recording months of data — showing trends of radiation with a data logger.

# Electronics

The brain of the counter is a PIC16F916 microprocessor. You will need to program it. (The chip included in the available kit is preprogrammed.)

Geiger tubes require high voltages – often over 500 volts. However, they pull a very small amount of current in micro-amps. The high voltage is generated by Q1 and Q2 and the choke. Q3 reduces the amount of power the unit uses, thus increasing battery life. A combination of high voltage capacitors and diodes increase the voltage as they are in a voltage tripler configuration.

A zener diode controls the voltage to the tripler via feedback to Q1. I used a 270 volt surface-mount zener. In theory, if tripled it should produce 810 volts; in practice, it produces 600. Keep in mind that the circuit generates very little current. Therefore, trying to measure it with a standard DVM will load down the voltage reading. Touching any part of the high voltage circuit will give a startling effect.

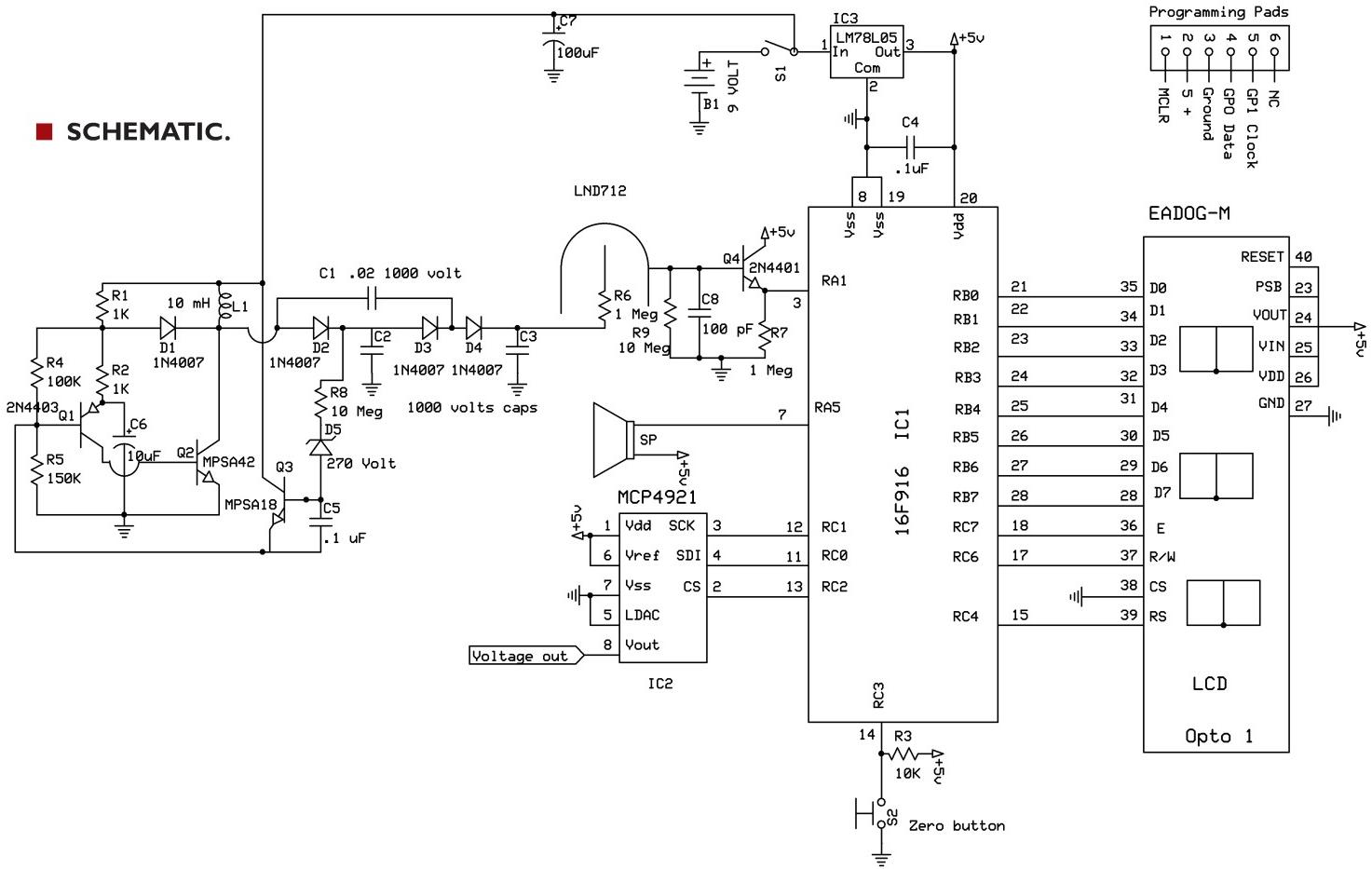


The output from the tube (note it comes from the case of the tube) is converted to a suitable voltage using Q4 as an NPN transistor to the microprocessor. The micro has a built-in timer and is capable of counting seconds, minutes, hours, and days. A momentary switch programs the time for collection which is displayed on the LCD.

The number of counts per minute are converted by the digital-to-analog converter (DAC); this voltage is available via the RCA jack.

The unit is housed in a Serpac case with a nine volt battery insert.

## ■ SCHEMATIC.

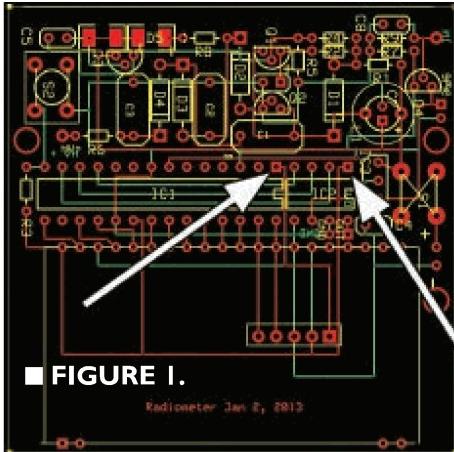


# Building the Unit

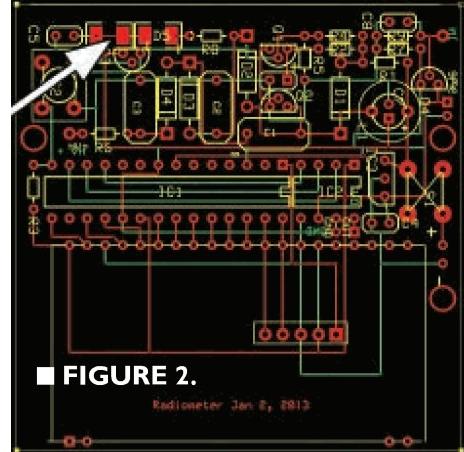
The board files from [ExpressPCB.com](http://ExpressPCB.com) are located at the article link, along with assembly files for the microprocessor. The microprocessor can be programmed on the board using a PICkit 2 programmer.

Solder IC1 and IC2 to the top of the board noting pin 1 has the square pad; see **Figure 1**. D5 is the surface-mount zener and has an indented line across one end. This is the cathode.

Solder D5 to its pads. You will see another set of pads to the left of D5 with a trace across shorting the pads; refer to **Figure 2**. Do **NOT** solder D5 to these pads; they are for an extra zener if you're using a Geiger tube other than an LND 712. Solder the remaining



**FIGURE 1.**



**FIGURE 2.**

diodes, noting their polarity. Solder IC3, paying attention to its flat side so it's pointing to the switch. Solder in the transistors. Solder C4, C5, C8, and C6, noting polarity and all the resistors. Solder the two switches and the LCD.

## PARTS LIST

ITEM	DESCRIPTION	PART #	QTY	COST	TOTAL	SOURCE
BH	Heavy duty 9V snap connector	234K-ND	1	\$0.55	\$0.55	Digi-Key
Box	4.38 x 3.25 x 2.00 9V black	SR232-CB-ND	1	\$7.02	\$7.02	Digi-Key
C1-C2-C3	.02 µF 1,000 volt	594-S203M75Z5UN63J0R	3	\$0.24	\$0.72	Mooser
C4-C5	.1 µF	0-FK18X7R1E104K	2	\$0.08	\$0.16	Mooser
C6	10 µF	581-TAP106K010SCS	1	\$0.52	\$0.52	Mooser
C7	100 µF 16 volt	140-REA101M1CBK0611P	1	\$0.09	\$0.09	Mooser
C8	100 pF	594-D101G29C0GH63J5R	1	\$0.19	\$0.19	Mooser
D1-D2-						
D3-D4	1N4007	512-1N4007	4	\$0.14	\$0.56	Mooser
D5	Zener	78-BZG03C270	1	\$0.20	\$0.20	Mooser
IC1	PIC16F916	PIC16F916-I/SP-ND	1	\$3.84	\$3.84	Digi-Key
IC2	DAC 12-bit	MCP4921-E/P-ND	1	\$2.36	\$2.36	Digi-Key
IC3	Five volt voltage regulator	497-2952-5-ND	1	\$0.10	\$0.10	Digi-Key
J1	RCA phone jack	CP-1412-ND	1	\$1.52	\$1.52	Digi-Key
L1	10 mH (millihenry)	963-LHL08NB103J	1	\$0.26	\$0.26	Mooser
Opto1	LCD display	790-EADOGM162LA	1	\$11.41	\$11.41	Mooser
Q1	2N4403	610-2N4403	1	\$0.28	\$0.28	Mooser
Q2	MPSA42	2-MPSA42	1	\$0.28	\$0.28	Mooser
Q3	MPSA18	863-MPSA18RLRAG	1	\$0.35	\$0.35	Mooser
Q4	2N4401	610-2N4401	1	\$0.28	\$0.28	Mooser
R1-R2	1K	1.0KEBK-ND	2	\$0.10	\$0.20	Digi-Key
R1-R2-R3	10K 1/6W	10KEBK-ND	3	\$0.18	\$0.54	Digi-Key
R4	100K	100KEBK-ND	1	\$0.10	\$0.10	Digi-Key
R5	150K	150KEBK-ND	1	\$0.10	\$0.10	Digi-Key
R6-R7	1 megohm	1.0MEBK-ND	2	\$0.10	\$0.20	Digi-Key
R8-R9	10 megohms	10MEBK-ND	2	\$0.10	\$0.20	Digi-Key
S1	Switch push DPST 0.1A 32V	401-1132-ND	1	\$1.45	\$1.45	Digi-Key
S2	Switch tactile SPST-NO 0.02A 15V	EG1866-ND	1	\$0.19	\$0.19	Digi-Key
Speaker		433-1079-ND	1	\$1.81	\$1.81	Digi-Key
<b>HARDWARE</b>						
Standoff	3/8 6-32	885K-ND	2			Digi-Key
Screw	6-32 1"		2			
LND712	Geiger tube		1			

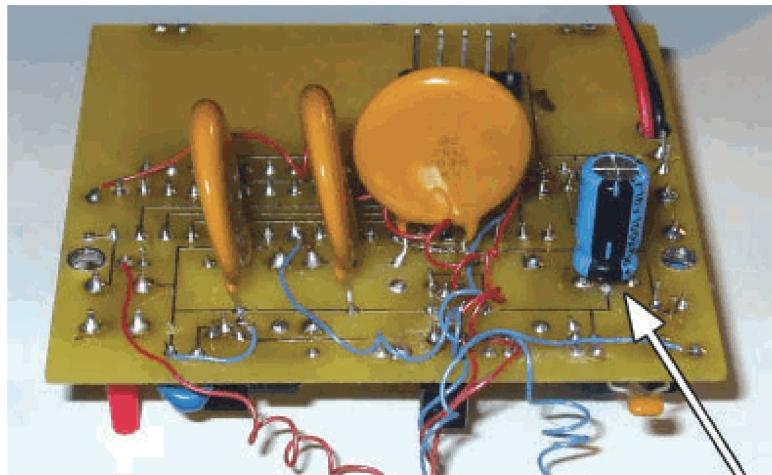
Prices are subject to change without notice.

Now, turn the board over and place C1, C2, and C3 on the bottom side and solder. C7 also goes on the bottom side. Lift it off the board about 2-3 mms so you can solder L1. Note its polarity and solder; refer to **Figure 3**.

Place L1 on the top of the board and solder.

■ **FIGURE 3.**

A complete kit to go with this article can be purchased online from the *Nuts & Volts* Webstore at [www.nutsvolts.com](http://www.nutsvolts.com) or call our order desk at 800-783-4624.



## Chassis

Using the four screws, attach the top and the bottom of the chassis together. The screws will self tap and it will make it easier for final assembly; secure the box for drilling.

Go to the article link and download the template. When you cut out the template, glue it to the top and sides of the box. The battery box should be on the top. Drill the holes as marked and deburr them as necessary. Hot water will remove the templates.

Place the nine volt battery snap inside the chassis (facing the bottom), and run it through the slot on the right side. Run the battery wires through the strain hole of the board and solder the red wire to the + and the black wire to the -. Solder the wires; refer to **Figure 4**.

Using two 3/8" standoffs, mount the board to the top chassis using 1/2" 6-32 screws. The holes in the board will self thread.

The end window of the LND 712 is very thin and fragile, and is easy to poke a hole into. (I speak from experience.) Strip a 4" piece of #30 blue wire wrap on the short wire coming from the side of the tube.

Solder a 4" #30 wire wrap red wire to the end clip of the Geiger tube. Place a piece of insulated tubing over the end clip to prevent shock. Coil both the wires.

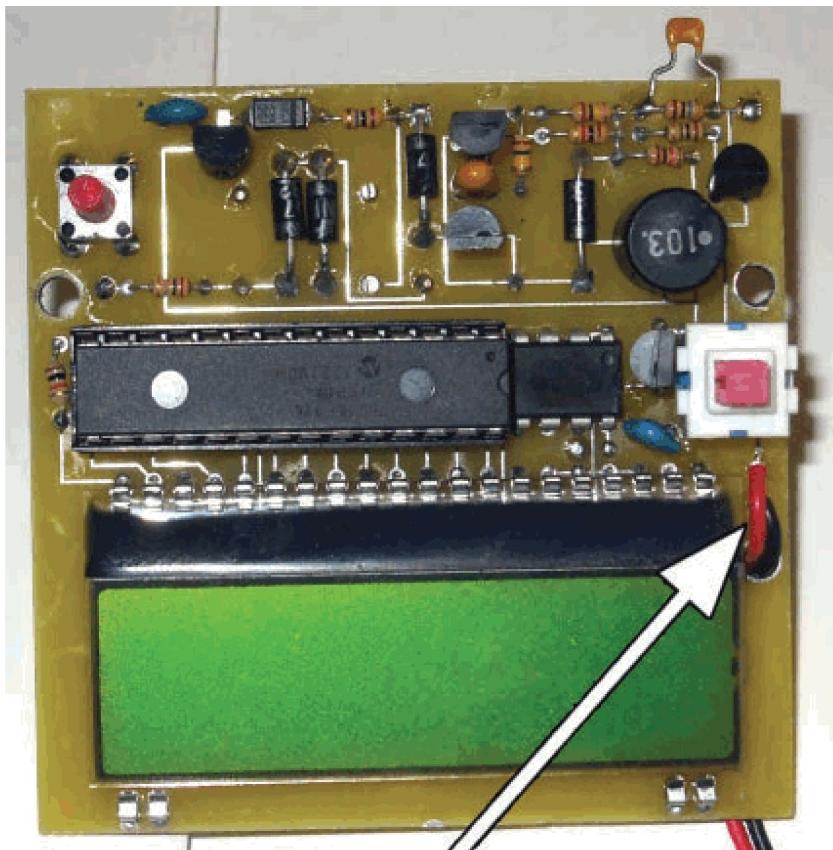
Mount the Geiger tube next to its hole using a hot glue gun. Looking at the bottom of the board, solder the red wire to the HV+ pad and the blue wire to the IN pad.

Wire wrap a 4" red wire to the + post of the speaker and a 4" blue wire to the other post. Coil the wires. Glue the speaker to the side of the box with hot glue. Solder the blue wire to the round pad and the red wire to the

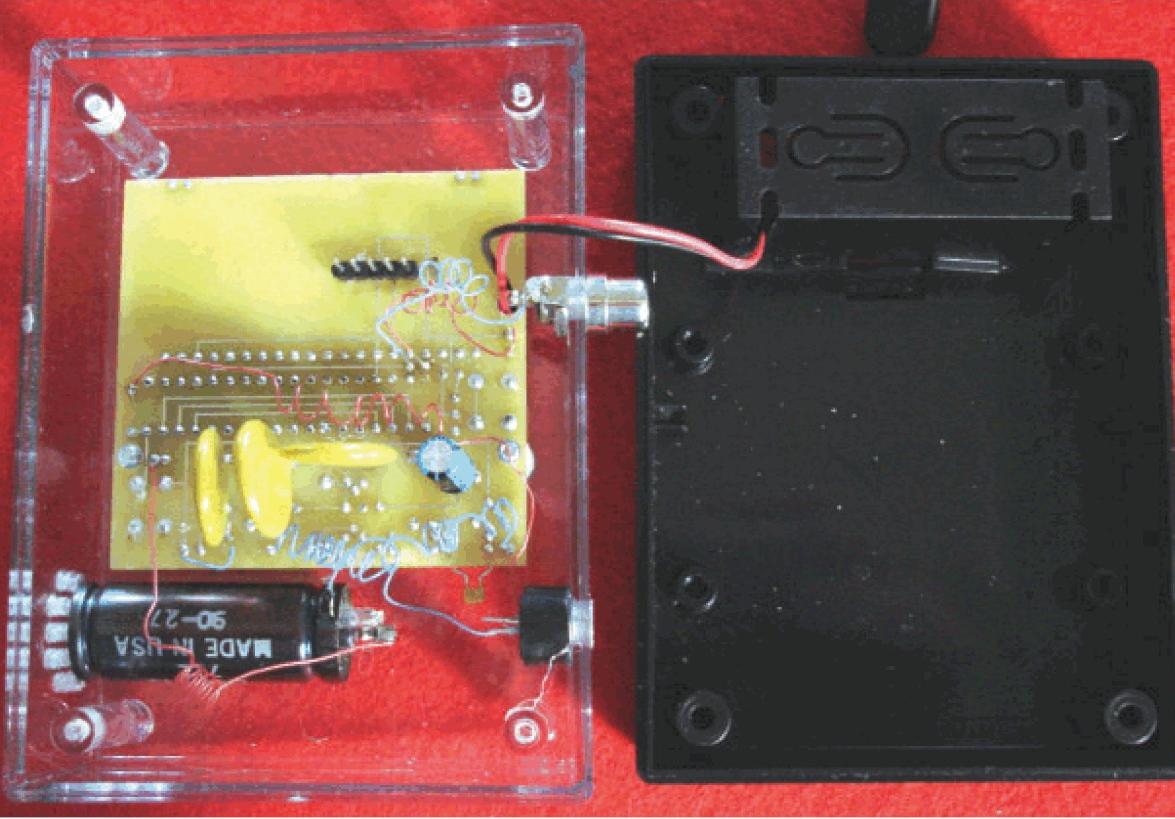
square pad on the ones marked SPK.

Place the RCA jack into its hole. Solder 4" of red and blue wires to the RCA jack. Red goes to the center pin. Solder the red wire to the square pad (pin 8, IC2) and the blue wire to the round pad (pin 7, IC2). Coil the wires using a 1/8" diameter screw driver or 1/8" drill, and coil the wires for easy storage.

Secure the box with the four screws.



■ **FIGURE 4.**



## Testing the Unit

Snap a nine volt battery into the battery clip. Push the on-off switch. The display should show a readout in CPM (counts per minute) which is the default. As radiation is detected, a click will be heard and the counter will increase. Pushing the mode button will advance the display from rems (the unit of radiation dosage — such as from X-rays — applied to humans) per minute, hours, and days. If the mode button is held down for more than five seconds, it will reset all the counters and registers.

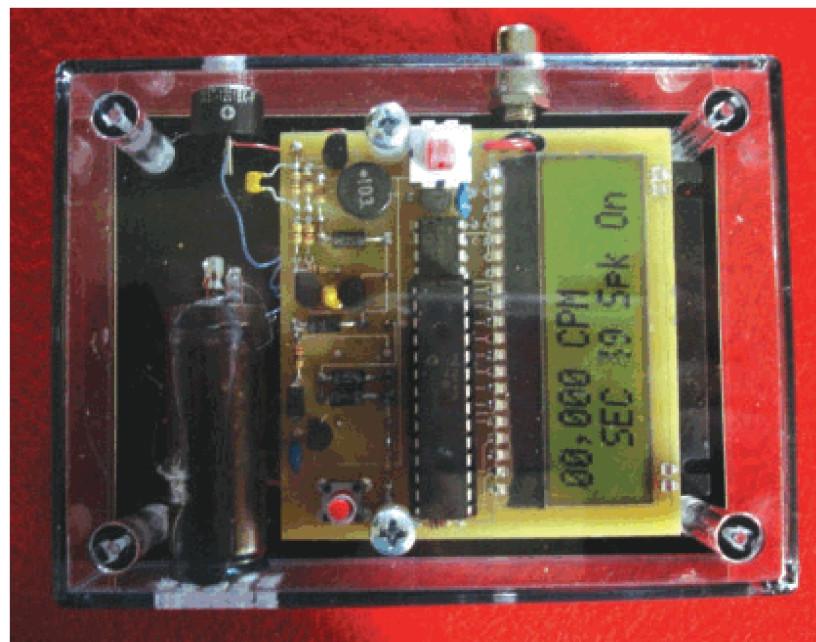
If in micro-rems per minute, the unit will count 60 seconds and then latch the counter showing the count for that particular minute. The unit will still be counting — as demonstrated by the click and the flashing of a † on the display — but it will not display a running count until the next minute. A countdown in seconds will be shown until the results toggle. The same occurs for hours and days. The unit will automatically change from micro-rems to milli-rems as needed.

The unit will sound an alarm for five seconds if the count exceeds a calculated .5 micro-rems in a minute period (30  $\mu\text{R}/\text{Hr}$ ). To turn off the alarm and beeping, turn the entire unit off and hold the mode button down; then turn the unit on again.

The background count will vary with the area you live in; 12  $\mu\text{R}/\text{Hr}$  is about average. I get 20 per hour at my laboratory; this is probably due to

the altitude of Carson City. Before 9-11, I took the unit in an airplane and turned it on at 35,000 feet. It will make you wonder why you are flying; it registered 300  $\mu\text{R Hr}$ .

Pick up a Coleman lantern mantle and use this to test the unit. It contains thorium that is radioactive and emits alpha particles. The unit draws about 10 mA, and a nine volt battery will last about two days. Use a nine volt DC battery eliminator if recording for days or months.



## Making a Radiation Graph

I use two types of devices for making graphs. The first is a Dataq EL-USB-3 which is a voltage data logger that plugs into the USB port of a computer. This device makes the Geiger counter truly portable. It sells for about \$75. It measures 0-30 volts, and can be set to record from one second to a 12 hour interval. At one minute intervals, it will record 22 days of data. It is only sensitive to 50 mV which is 41 CPM.

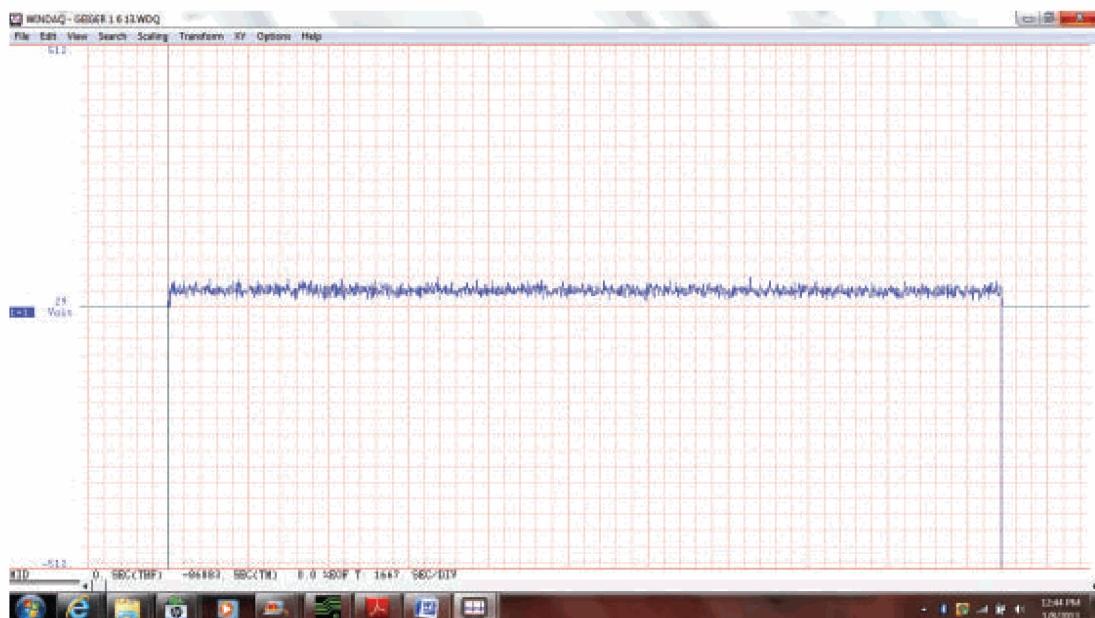
The second device I use is my favorite. It is the Dataq DI-145 which sells for \$29. It is a must for any scientist.

Most of us have an older computer sitting around gathering dust that we can utilize with this unit.

The device will record up to four channels at one time and with Dataq's free WinDaq's software, it is

a very powerful tool. You can monitor gravity, the tilt of the earth, plus seismic activity, magnetic fluxuations, and radiation all at the same time, so you can observe any correlations.

The software graphs out all on the same sheet. Just plug in either device into the RCA jack. Its sensitivity is .001 volts which is 1 CPM.



## What Are We Measuring?

Well, as usual, when entering in the scientific world there is a plethora of terms and units. Fortunately, for our purposes, one roentgen equals approximately one rad, which equals one rem.

A rad (Radiation Absorbed Dose) is the unit for measuring absorbed doses of radiation. The rem (Roentgen Equivalent Man) is the damage that one roentgen causes to humans. The roentgen is the quantity of X-rays or gamma rays.

One roentgen is a lot of radiation and is equivalent to about three to five years of normal exposure. This is why milli-roentgens and micro-roentgens are used. A milli-roentgen is equal to 1/1000 ( $1 \times 10^{-3}$  roentgens) and a micro-roentgen is

equal to 1/1,000,000 ( $1 \times 10^{-6}$  roentgens). The unit we are building measures in micro-roentgens.

Due to a number of factors (type of tube, calibration, and different types of radiation), consider one click or one count 1/105 of a micro-roentgen ( $1 \times 10^{-6}$  roentgens).

There are three main types of ionizing radiation. (Ionizing radiation causes changes in tissues and can cause cancer.)

Alpha particles are positive charges that are very short lived. A sheet of paper can stop them, however, if ingested or inhaled they become very deadly. Radium is a naturally radioactive element. When it emits an alpha particle, it becomes radon — a radioactive gas with a half-life of 3.8 days. Just as there are earth tides, it has been reported that radon

tides also vary from day to day.

Beta particles are much smaller than alpha particles and are negatively charged, but can be blocked by a thin sheet of aluminum foil.

Gamma rays are electromagnetic radiation and are stopped by lead, concrete, or steel.

Depending on what you read, we are exposed to about 100–200 milli-roentgens per year. A chest X-ray (low level gamma rays) gives us about 10 milli-roentgens of exposure.

When should you become alarmed? This is difficult to say, however, the EPA forbids radiation exposure above five rems in any one year to radiation workers.

I hope you enjoy building and using this radiation counter. **NV**

## Hints & Tips

- To view and change the board files and schematic, go to [www.expresspcb.com](http://www.expresspcb.com) and download their free CAD software. There is no obligation and you will not be harassed by emails.
- Microchip provides free software for the programming of their microprocessors. Go to [www.microchip.com](http://www.microchip.com) for information.
- When using hour and day readings, until you get 60 minutes or 24 hours, the unit will show that it is counting and will give the number of hours to go.

### CHANGING VOLTAGES

D5 is a zener that changes the voltage. The one recommended is 270 volts. To get higher or lower voltages, change this zener. To the left of the zener is another set of pads. You can place zeners in series and add their voltages. If using a second zener, make sure you cut the small trace between the second set of pads.

Note: The generator cannot supply much current. An ordinary 10 megohm voltmeter will pull the output voltage quite low; a very high impedance voltmeter is needed to directly measure the output voltage.

Here is a technique you can use. Take a 100 megohm resistor and place it in series with the voltmeter probe. If you have a 10 megohm meter, this will give a 1:10 reduction. Measure the voltage from ground across the cathode of the zener diode. Note the voltage on the voltmeter and compare it to the voltage of the zener. Perform a ratio. This will correct for the meter's input resistance, e.g., voltage of zener = 270 volts; voltage on the meter is 20 volts:

$$\text{factor} = \frac{270}{20} = 13.5$$

Now, measure the voltage on the cathode of D4 and multiply it by the factor used. This will give you

(approximately) the correct voltage of the circuit.

If you use another tube besides the LND 712, check its specifications for the voltage needed to drive the tube.

### RECORDING USING WINDAQ

I normally record an event once per minute. Make sure you are only using one recording channel. To record, click "File" and then "Record." Make up a file name that you can remember. Once you name it, a window will pop up and ask for the number of kilobytes. Make sure you put enough in for 24 hours of recording. You can do this by holding down OK, and observing the hours and minutes. If this is not correct, move the arrow off of OK and input more or less KB. Click OK when finished.

You can change the units by clicking on "Edit." Go to the engineering unit settings and make five volts = 4096 counts.

When finished recording, click "File" and then "Close."

### REVIEWING DATA

Perform a search with the name you stored the data in. Click on it and the Windaq software should open. Press F7; it may take a few seconds to load. Click on "Maximum." The display should have 24 hours of data on one page.

### REFERENCES

The first Geiger counter I had was back in 1989 and was an Aware Model RM-60. They are still manufacturing counters, but they start at about \$180. They make a good product, however. On their website ([www.aw-el.com](http://www.aw-el.com)), they have a lot of information on Geiger counters, including sites to experimentation. They also have methods of measuring radon that can be applied to this unit.

Check out <https://sites.google.com/site/diygeigercounter/gm-tubes-supported> for more information on different Geiger tubes.



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# Introducing Wi-Fi with the PIC 32-bit Micro Experimenter

By Tom Kibalo

We're going to introduce Wi-Fi applications by using the Roving Networks RN-XV Wi-Fi module and the PIC 32-bit Micro Experimenter (Experimenter for short). Our focus will be on Wi-Fi communication examples that can be useful for remote Wi-Fi sensors. The RN-XV is a self-contained Wi-Fi module, with lots of capability and — better yet — it is fairly inexpensive. The module interfaces to the Experimenter through a serial UART interface for both command and data transfer. The RN-XV does most of the heavy lifting for the Wi-Fi communications, leaving the Experimenter to focus on applications.

Back in the December 2012 issue, we introduced an Experimenter RF carrier board for use with the XBee to help in developing wireless sensor networks. The good news here is that the Roving Networks RN-XV fits the form and function of the XBee de-facto standard. This makes our RN-XV integration to the Experimenter straightforward when using the RF carrier board.

We will examine two configurations of the 32-bit



Figure 1. The 32-bit Experimenter with Wi-Fi.

Experimenter for use with the RN-XV, then a stand-alone battery powered configuration (without the Experimenter). These examples should provide many good ideas on ways to use the RN-XV in your own designs.

The first configuration is designated as the “evaluation mode.” It’s the best setup to get your feet wet. You simply plug the RN-XV into the Experimenter (using the RF carrier board), and then hook up the Experimenter via its USB to your PC for direct control. The second configuration is “stand-alone mode” which has no direct hookup to your PC, but still uses the Experimenter. This is closer to how you may actually use the RN-XV for a full capability deployment.

The final configuration is “remote battery stand-alone” which does not use the Experimenter. It runs the RN-XV off a battery as a limited function remote Wi-Fi sensor. We will also introduce some new software tools, and work through several exercises and setups with these configurations. All the code is available for download at the article link. All software tools are free and available from the designated vendor websites.

The network communications used with these exercises incorporates TCP (Internet Transmission Control Protocol). TCP provides a reliable, guaranteed point-to-

point ordered delivery of data from one network device to another. This type of communication is ideal for remote sensing and control applications.

## Evaluation Configuration Setup

To begin, just plug the RN-XV into the RF carrier board, then mount this on to the Experimenter. It, in turn, connects to a PC through its USB. The RN-XV supports a standard PC or microcontroller interface with an API (Application Programming Interface). The API and other module features are covered in the module user manual; it is highly recommended that you acquire and review this "Wifly" user manual to gain a complete understanding of the API and its capabilities. You need to install Tera Term software on the PC to be able to interact with the RN-XV API through the serial USB. This software and the Wifly manual are both available from Roving Networks at [www.rovingnetworks.com/resources/show](http://www.rovingnetworks.com/resources/show).

The 32-bit Experimenter also needs to be programmed to support this configuration. The software is at the article link and is a MPLAB X IDE project which was written using the Microchip XC32 C complier. Both the MPLAB X IDE and XC32 are available at [www.microchip.com](http://www.microchip.com).

Here are the steps to set up the Evaluation Configuration:

1. Connect a power source +5V-6V DC to your Experimenter power input pins. Wire the RF carrier module for the same external power by setting its J2 PWR SEL jumper for pins 1 and 2, and then route the same Experimenter +5V-6V DC input power source to the carrier J1 plus and minus connections.
2. Populate the carrier with the RN-XV module. In this configuration, both the Experimenter and module are driven off the same external power sources.

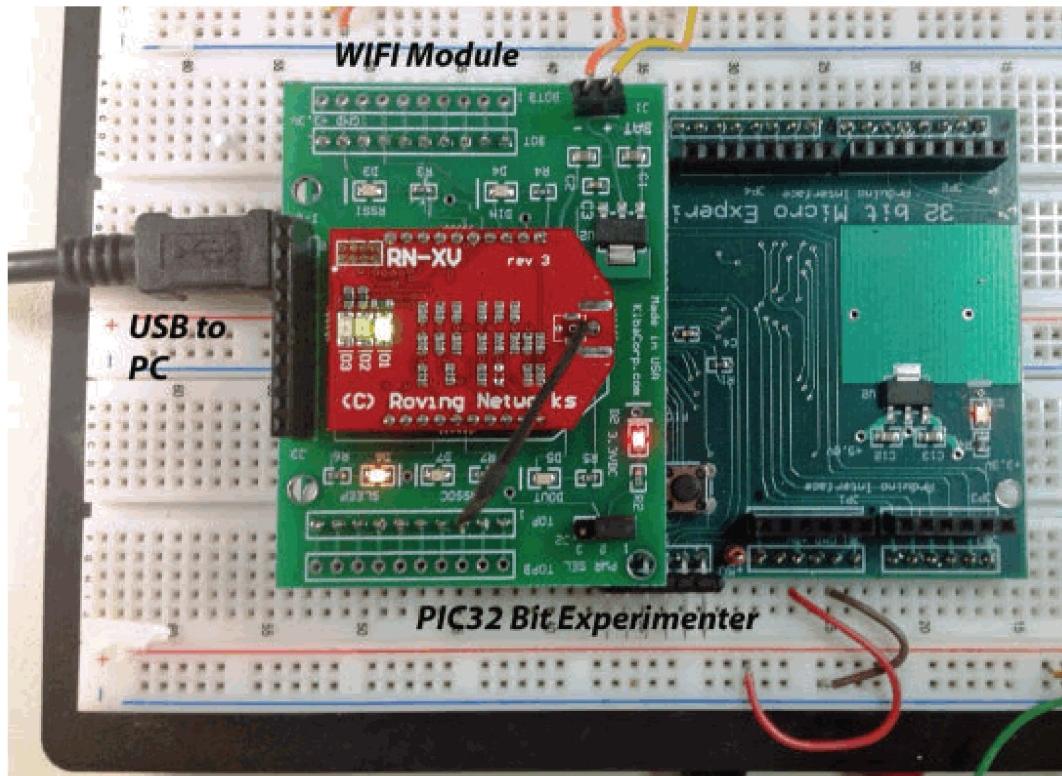


Figure 2. The evaluation configuration.

3. Open the USB project software with MPLAB X. Use a Microchip PICkit 3 programmer/debugger (or equivalent) to build and program the Experimenter. Remove the PICkit 3; the Experimenter should be running.
4. Connect the Experimenter USB to the PC USB. The PC should automatically configure its USB with the required USB drivers.
5. Install Tera Term onto your PC from the Roving Networks website.
6. Launch Tera Term on your PC. It should identify a COM port for the Experimenter. Select this COM port and configure the serial port for 9600 baud, no parity, one stop bit, and no hardware flow control.
7. Once this is done, type " \$\$ \$" (no carriage return) in the Tera Term terminal window. You should see the "cmd" response from the RN-XV. You are now in command mode and ready to start Wi-Fi module association. You can exit command mode at any time and enter data mode by typing "exit" (CR), but don't do that just yet. Let's first review basic Wi-Fi association, which is an important primer for our next experiment.

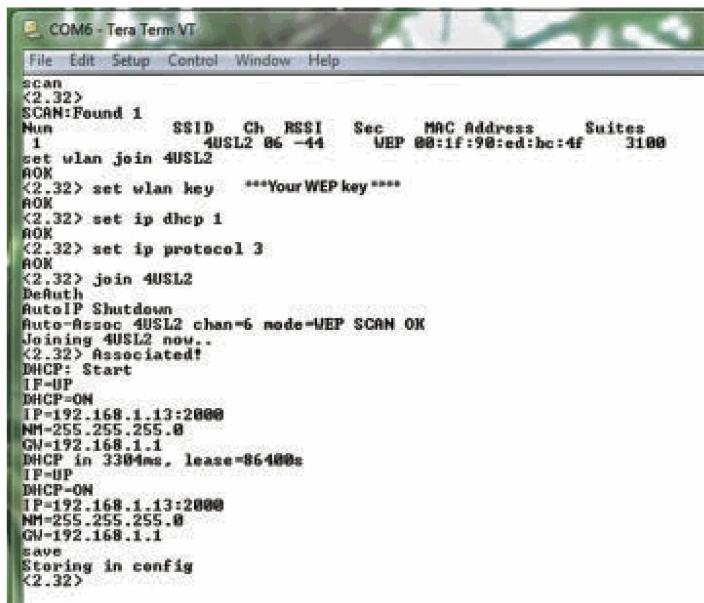
# A Primer: Association With a Secure Wi-Fi Access Point

Built into every Wi-Fi access point and device is a security feature called authentication; it is designed to prevent Wi-Fi eavesdropping from unauthorized devices. Different Wi-Fi authentication based algorithms used by the industry include WEP-64, WEP-128, WPA2-PSK, WPA1-PSK, and WPA-PSK. The RN-XV supports all of them. You just need to select which of these is appropriate for your target access point, and determine if they require a password or key. You need to know what is required and the actual contents of either the key or pass phrase to successfully associate.

Authentication is performed as part of a larger Wi-Fi device initialization process coined “association.” This is a four step process that is analogous to the creation of a virtual wire between the device and an access point. The end result of association is that your device receives an IP (Internet protocol) address to enable communications to any part of the network. This address is four bytes, depicted as a dotted-quad such as 192.168.1.100. Dynamic Host Configuration Protocol (DHCP) is the network protocol used during association to configure a network device with an IP address. The Wireless Access Point has a DHCP server function built in. The RN-XV has a built-in DHCP client to automatically work with the access point server. The overall association process is shown in **Figure 3**. The IP address can also be assigned manually, if needed.

## Experiment 1: Associating RN-XV with a Secure Access Point

The RN-XV module has two modes of operation: data and command. In data mode (the default on power-up), the module performs like a data pipe. In other words, when data is received over Wi-Fi, the module removes the headers before transferring the data to the host microcontroller. Command mode is a special configuration which is entered with the host transmitting ASCII “\$\$\$” (no CR). It is used by the host to configure the RN-XV operation and monitor its status (using API ASCII commands).



COM6 - Tera Term VT  
File Edit Setup Control Window Help  
scan  
<2.32>  
SCAN: Found 1  
Num SSID Ch RSSI Sec MAC Address Suites  
1 4USL2 06 -44 WEP 00:1f:90:ed:bc:4f 3100  
set wlan join 4USL2  
AOK  
<2.32> set wlan key \*\*\*Your WEP key\*\*\*  
AOK  
<2.32> set ip dhcp 1  
AOK  
<2.32> set ip protocol 3  
AOK  
<2.32> join 4USL2  
DefAuth  
AutoIP Shutdown  
Auto-Assoc 4USL2 chan=6 mode=WEP SCAN OK  
Joining 4USL2 now...  
<2.32> Associated!  
DHCP: Start  
IP-UP  
DHCP=ON  
IP=192.168.1.13:2000  
NM=255.255.255.0  
GW=192.168.1.1  
DHCP in 3304ms. lease=86400s  
IP-UP  
DHCP=ON  
IP=192.168.1.13:2000  
NM=255.255.255.0  
GW=192.168.1.1  
save  
Starting in config  
<2.32>

**Figure 4.** The module command and response during association.

Command entry does require a CR, and the module will respond typically with an ‘AOK’ if everything is accepted or ‘ERR’ if it is not. If you type CR in command mode without a command, the module will respond with its version number like <2.23D>.

The RN-XV API command set falls into four general categories: SET, GET, STATUS, and ACTION (refer back to the Wifly manual for details). All configuration settings can be directed by the host to be stored in the module’s Flash memory, where it can persist and be reloaded after power cycling. To keep changes, the host uses the “save” command.

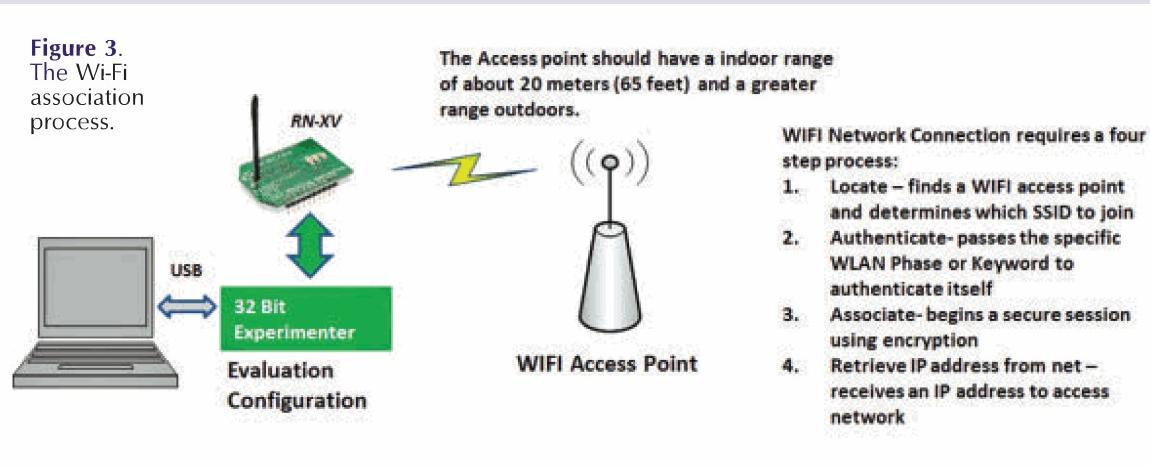
You should now be in Evaluation Configuration mode with Tera Term communicating with the RN-XV over USB. As you recall, we typed “\$\$\$” to enter the RN-XV command mode, then the module replies with “cmd.” Let’s now direct the module to search for access points by typing the command “scan” with (CR). The RN-XV will now automatically list all wireless access points it finds. In this example, only one access point was found.

You select an access point by identifying its SSID (name of access point) and security authentication (either key or pass phrase). The commands to do this are as follows:

1. Type “Set wlan ssid <string>” (CR).
2. Type “Set wlan pass <string>” (CR) or optionally “set wlan key <string>” (CR), depending on the specific access point authentication requirement.
3. Type “set ip dhcp 1” (CR) to activate the RN-VX DHCP client.
4. Type “ip protocol 3” (CR) to activate TCP and IP protocols.
5. Type “join <SSID>” (CR) to attempt to associate with the designated access point.

The results should look like **Figure 4**.

**Figure 3.**  
The Wi-Fi association process.



6. Type “save” (CR) to store the configuration into the module. This way (on power-up), the system will automatically associate with the designated access point.

If the association is successful, DHCP will assign the module an IP address; in this case, 192.168.1.13 (as well as confirm the IP address of the access point Internet gateway which is 192.168.1.1).

A fun way to verify the module’s presence on the network is to make use of the ping command, using Windows command window. Ping is a computer network administration utility used to test the reachability of a device on the Internet, and to measure the round-trip time for messages sent from the originating host to a destination computer.

Type “ping 192.168.1.13” at the command prompt and verify that the module is present on the network (see **Figure 5**).

A visual indication of connection status is readily available directly from the RN-XV itself by examining its three LEDs (red, yellow, green) that are located on the top of the module (**Figure 6**).

Before an association, both of the module’s red and green LEDs are blinking fast; after association, only the module’s green LED blinks slowly.

```
C:\Windows\system32\cmd.exe
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation. All rights reserved.

C:\Users\kibalo>ping 192.168.1.13

Pinging 192.168.1.13 with 32 bytes of data:
Reply from 192.168.1.13: bytes=32 time=8ms TTL=255
Reply from 192.168.1.13: bytes=32 time=1ms TTL=255
Reply from 192.168.1.13: bytes=32 time=1ms TTL=255
Reply from 192.168.1.13: bytes=32 time=1ms TTL=255

Ping statistics for 192.168.1.13:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 1ms, Maximum = 84ms, Average = 21ms

C:\Users\kibalo>
```

**Figure 5.** Utilizing ping.

Condition	Red LED	Yellow LED	Green LED
On solid	-	-	Connected over TCP
Fast blink	Not associated	Rx/Tx data transfer	No IP address
Slow blink	Associated, no Internet	-	IP address OK
Off	Associated, Internet OK	-	-

**Figure 6.** The RN-XV module LED activity matrix.

Congratulations! You should now have an associated module with IP address to use in your experiments!

# Stand-alone Experimenter Configuration

Let's run a stand-alone configuration next. Here, we remove the Experimenter from the PC USB, but retain the RF carrier board with the pre-configured RN-XV module from our previous experiment. We then add an Experimenter color display carrier module and a PS/2 keyboard interface (this carrier module is available from the Nuts & Volts Webstore).

This new configuration acts as a self-contained Wi-Fi device (with the use of a PC), and can interact with the PC or other Wi-Fi devices as a stand-alone. We will need to configure the Experimenter software again.

Navigate with MPLAB X to the Wi-Fi demo folder and open the project software "lab3.X." Program the Experimenter as before with the PICkit 3 and then remove it. Connect a PS/2 keyboard to the color display carrier module; you should see the Experimenter automatically associate with the access point and receive its IP address. In this specific example, the RN-XV IP is 192.168.1.6 with a default port number of 2000.

The IP address is the routable network address of the device tied to the network, but what is the port number? Port numbers provide access to a host device application that uses the IP address. The port number is a 16-bit

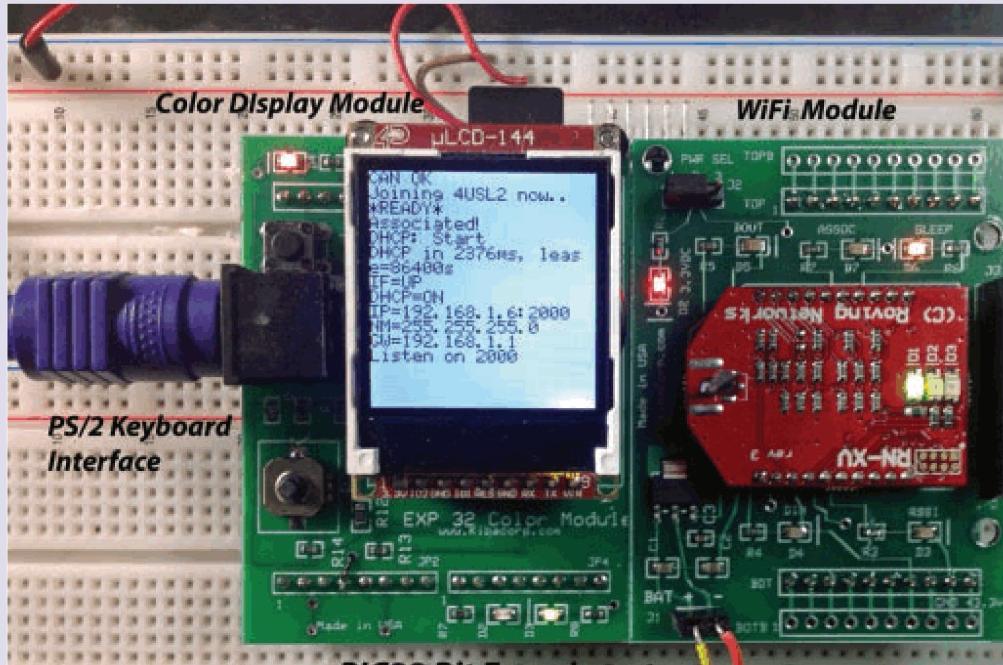


Figure 7. The stand-alone configuration showing the association complete and the IP address assigned.

unsigned integer (1 to 65535; 0 is reserved). Because of the limited size of the display (only 20 characters by 15 rows and a 5x7 character font), there is some wrap-around text.

The display will automatically pause once it fills up the screen. You'll need to type a (CR) on the keyboard to see the rest of the display when this happens. You are now in business to conduct any RN-XV experiment.

Let's move on to our TCP exercises by entering command mode (type "\$\$\$").

## Experiment 2: Sending Data From the Experimenter to the Host Using TCP

In command mode, we will open a TCP connection to the host computer, and then pass TCP messages to the remote PC by simply typing on the PS/2 keyboard. This exercise is generally representative of a remote sensor application. Also keep in mind that a TCP connection is a one way communication (see **Figure 8**).

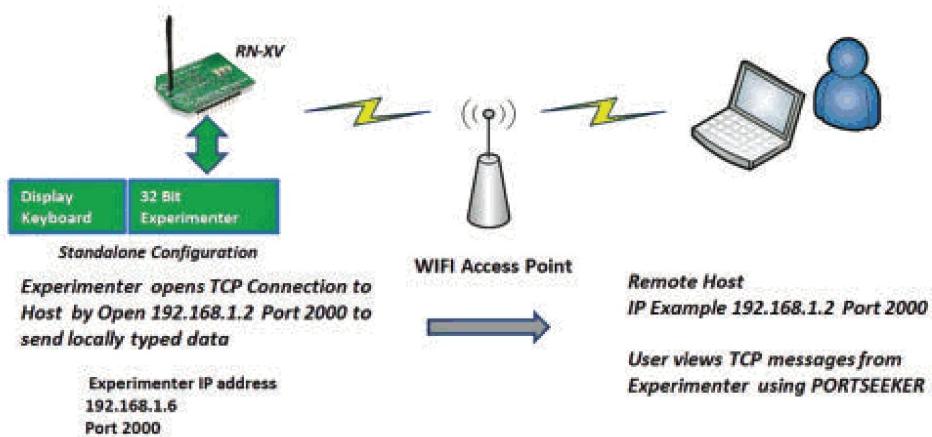
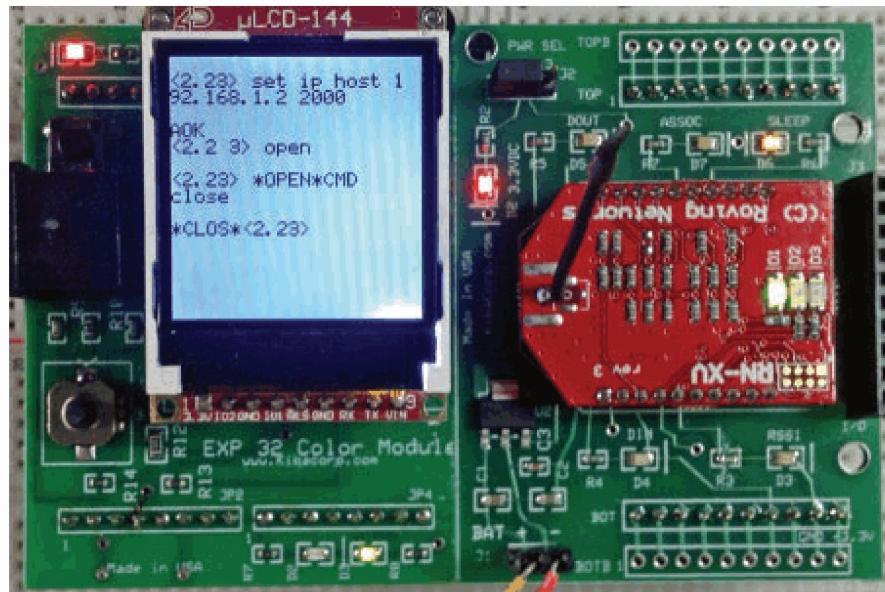


Figure 8. Sending data from the Experimenter to the PC using TCP.

On the Experimenter side:

1. Type “set <host IP> < port>” (CR) to select a host. To obtain the PC host IP address, execute the IPCONFIG command in the host PC command window, and then use the host IP address shown.
2. Type “open” (CR) to request a host connection.
3. If the host is ready and accepts the connection, there will be an \*OPEN\* response on the Experimenter display.
4. Once the connection is accepted on the host side, the Experimenter will enter its data mode. Any subsequent typing on the Experimenter side ends up as TCP messages picked up by the host. In our case, we typed “Cool.”
5. To close the connection, type “\$\$\$\$” and re-enter command mode, then type “CLOSE” (CR). A \*CLOS\* message will appear on the display, signifying the connection is indeed closed.

To accept a TCP connection from the Experimenter at the host as well as to see the TCP messages, we will use



**Figure 9.** The Experimenter side opening and closing a TCP connection to the host using Wi-Fi.

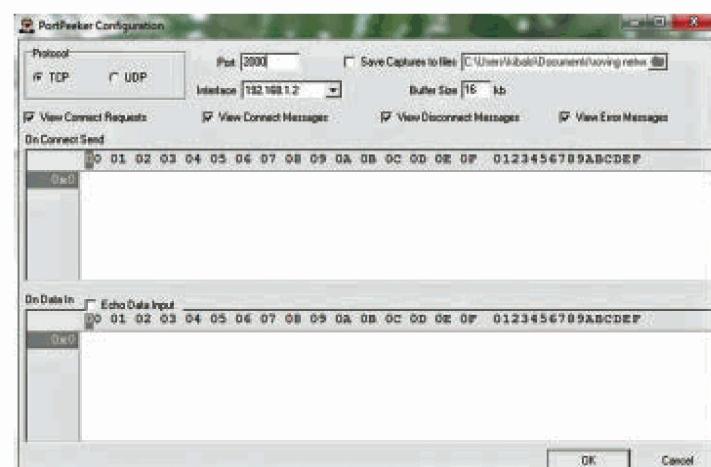
the software tool PORTPEEKER (available free from Roving Networks) on the host side. You must first install PORTSEEKER on your host PC.

Open PORTSEEKER and configure your host IP (should be automatically set) and then set port to 2000. Click on the OK button once you are done.

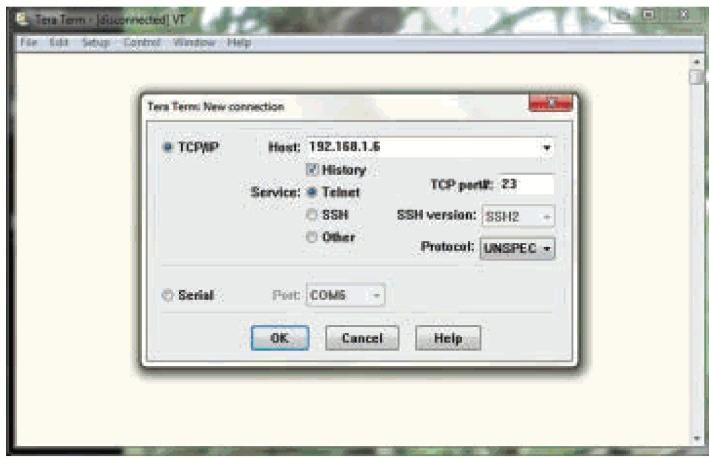
Once the TCP connection is made, the Experimenter should show \*OPEN\* on its display. Another message — \*HELLO\* — should appear simultaneously on PORTSEEKER. Any typed data from the Experimenter should also be displayed locally and captured by PORTSEEKER. Check out **Figure 11** to see that the TCP messages captured “COOL”. To close the TCP connections, just enter command mode and type “close” (CR) on the Experimenter side, or shut down PORTSEEKER on the host side.



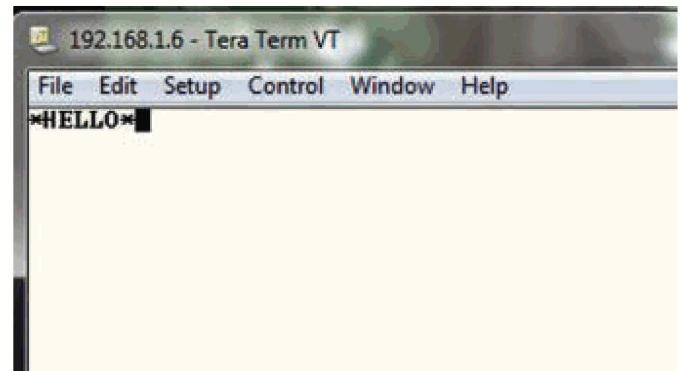
**Figure 11.** PORTSEEKER capturing TCP messages from the Experimenter.



**Figure 10.** Set up PORTSEEKER for the TCP IP and port.



**Figure 12.** Setting up Telnet for the Experimenter IP and port address.



**Figure 13.** Running the Telnet TCP connection.

## Experiment 3: Host Sending Data to the Experimenter Using TCP

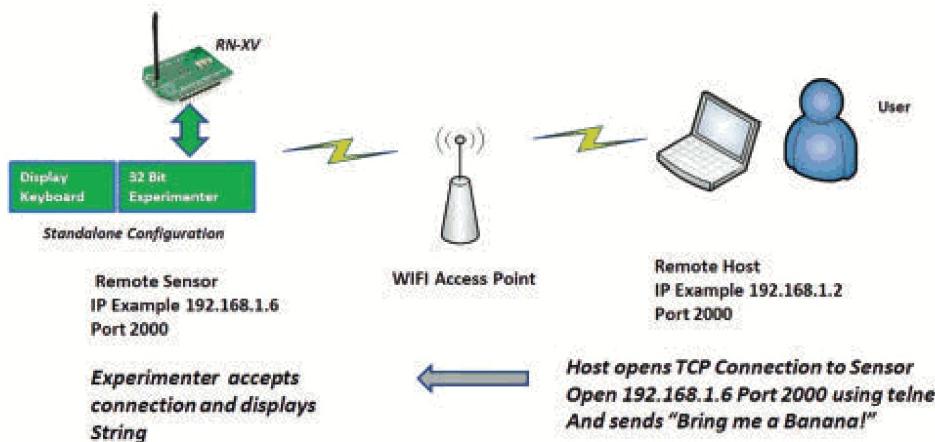
We will now use Telnet on the host side. Telnet is a network protocol used on the Internet to provide an interactive text-oriented communication facility using a virtual terminal connection over TCP. Tera Term is easily

configured for Telnet. No special Experimenter software or hardware is required other than the reuse of Experiment 2 code and the hardware configuration.

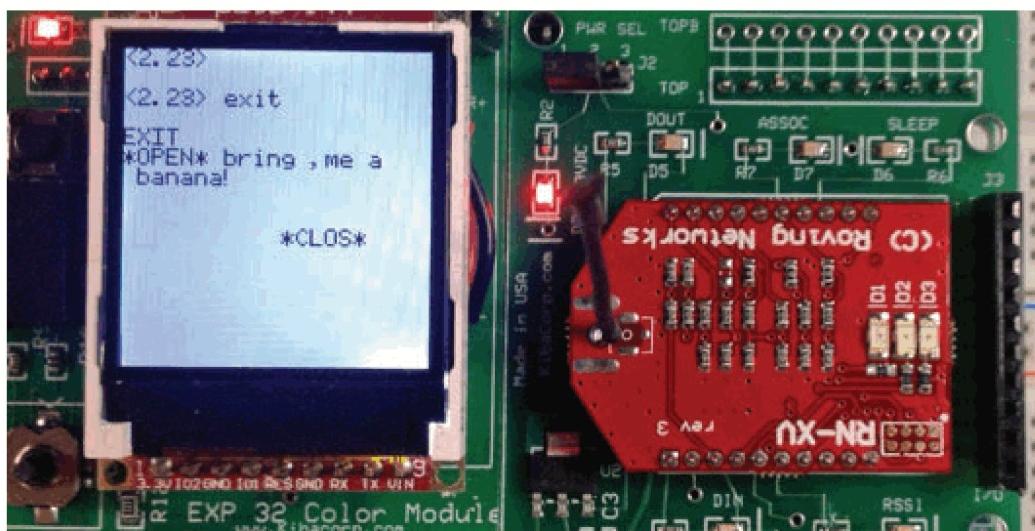
Acquire the Experimenter IP and port address by typing "get IP" (CR) while the RN-XV is in command mode. Then, place the Experimenter into data mode by typing "exit" (CR).

On the host side, use Tera Term for a Telnet connection set up for the Experimenter IP and port address. Once initiated, the Experimenter should display an \*OPEN\* message to indicate that the TCP connection is open with the host, and then a \*CLOS\* to indicate it is closed. The TCP Telnet window will display the message \*HELLO\* simultaneously with the \*OPEN\* message displayed on the Experimenter.

All subsequent host data typed in the Tera Term window during a Telnet session should appear automatically on the Experimenter display. None of this data will appear in the Telnet window. To mimic a remote command, we chose the phrase, "Bring me a banana!"



**Figure 14.** Receiving host commands.



**Figure 15.** TCP messages received by the Experimenter during a host Telnet session.

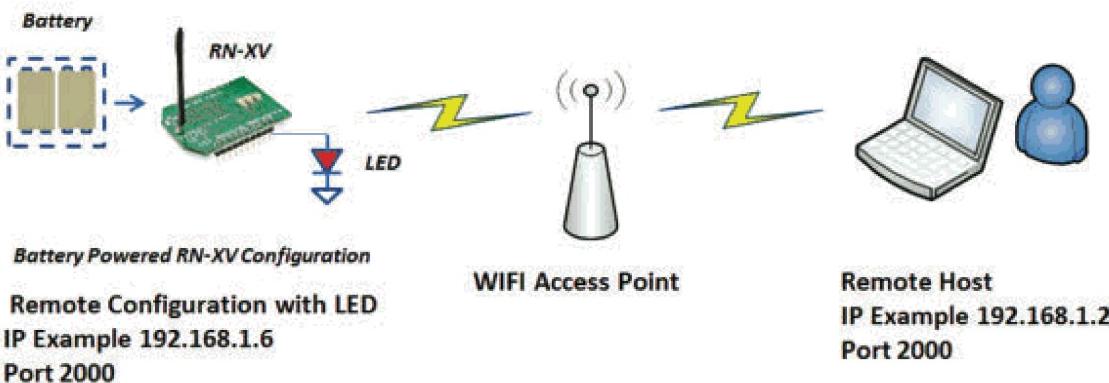


Figure 16. Battery powered configuration.

## Experiment 4: Stand-alone RN-XV Battery Powered Configuration

For this configuration, remove the RF carrier board with the Wi-Fi module from the Experimenter, apply battery power to the module, and interact with the module directly. We will use the TCP to remotely control an LED from the host.

For batteries, we need to supply +4.5V to 6V to the module; three to four AAA batteries should do the job nicely. We will use the J3 I/O port of the RF module for external electronics. For this experiment, we will connect a 1K resistor to the anode of an LED to pin GPIO 13 pin 7. This GPIO pin defaults to an output. Connect the cathode of the LED to ground (J3 pin 10).

Open Tera Term (configured for Telnet) using the IP address of the module, and the port address 2000. You can double-check you have the right address by utilizing ping. Tera Term should respond with an \*OPEN,\* indicating a TCP connection. Type " \$\$ \$" to enter command mode.

We can control the state of the LED through the RN-XV I/O commands (detailed in the API). In the set, "sys output <value> < mask>" (CR), value is what is written and mask designates the pins. Type "sys output 0x2000 0x2000" (CR) to turn the GPIO 13 LED on and "sys output 0x0000 0x2000" (CR) to turn the GPIO 13 LED off.

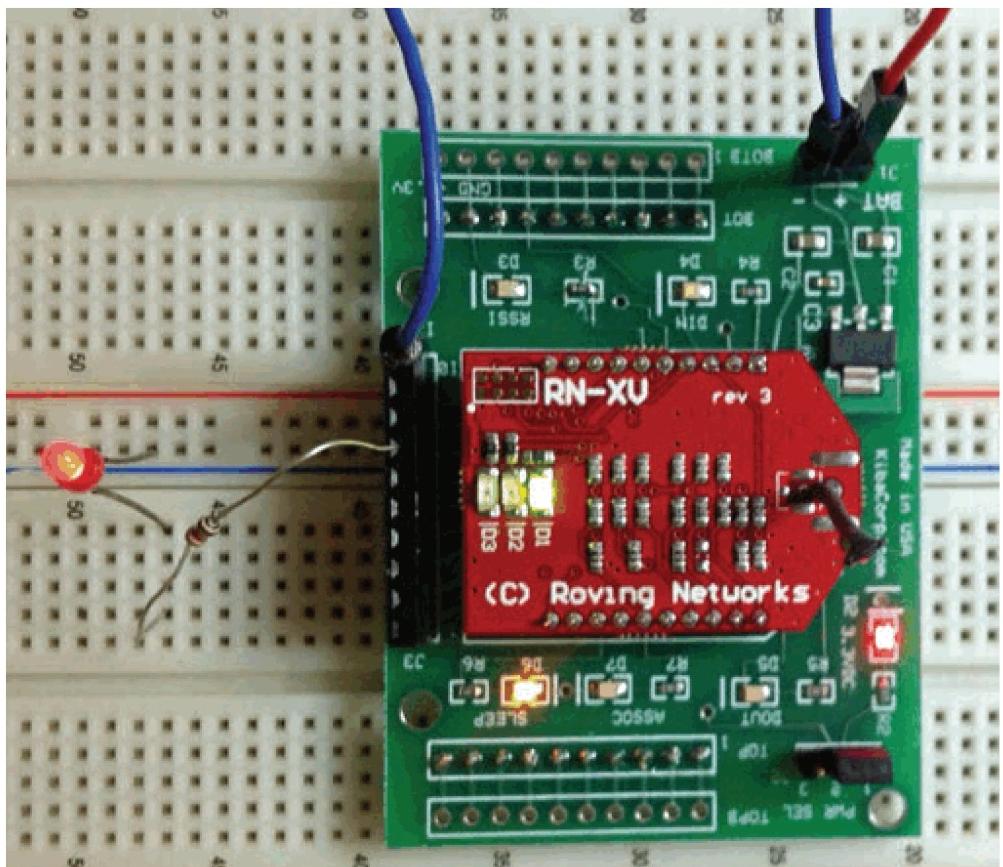


Figure 17. Battery powered configuration controlling LED.

## What's Next?

We covered some important ground in Wi-Fi, but have barely touched on all of the extensive capabilities of the Roving Networks Wi-Fi module. Wi-Fi can be tricky. However, the software tools, code examples, and hardware used here should be invaluable in your future Wi-Fi applications.

Future articles will cover FTP, HTML clients, and UDP applications. The Experimenter is readily poised to handle your wireless applications. Until next time, happy 32-bit Wi-Fi computing! **NV**

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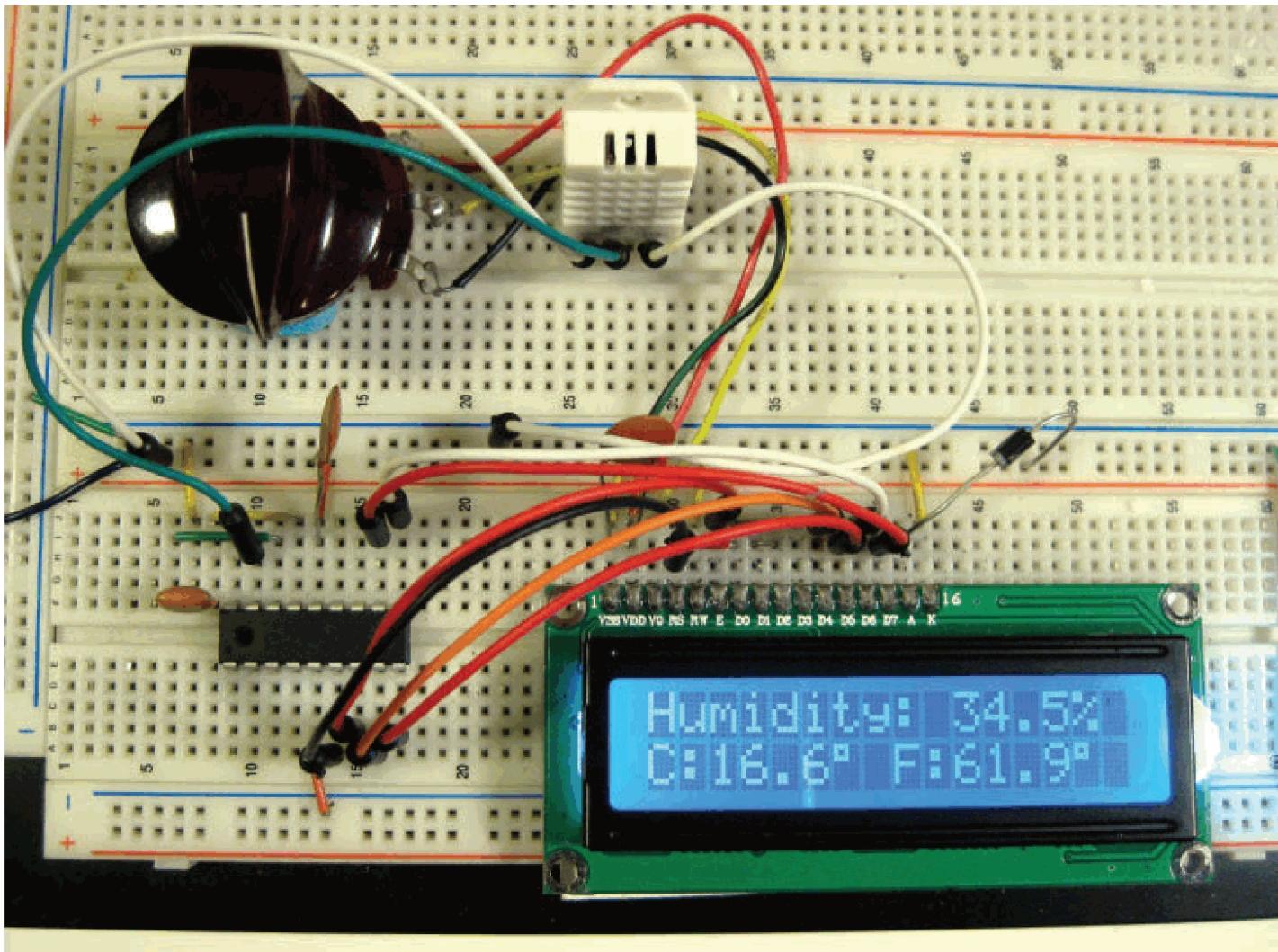
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A circular graphic containing a stylized, cartoonish robot eye with a thick black outline and a single black pupil, positioned to the right of the company name.

# The DHT22 Humidity/ Temperature Sensor Demystified

By Thomas Henry



Keeping tabs on relative humidity and temperature is important in a variety of situations. Museums often need to monitor these conditions in order to preserve rare artifacts. Musicians are concerned about the effects on their stringed instruments. Cigars and other natural products are often stored in climate controlled boxes. Not to mention, of course, homeowners who are concerned about the comfort level within their own homes.

The DHT22 is a recent contribution to the lineup of joint humidity/temperature sensors. It is particularly attractive to DIYers thanks to its low cost, which is around \$10. It spans an impressive range of 0% to 100% relative humidity, and -40° C to 125° C (that's -40° F to 257° F). Of course, it's doubtful any homebrew circuits could operate at these two extremes of temperature, but it's nice to know the sensor won't be the limiting factor. The claimed accuracy is ±5% worst case for humidity and ±0.2° C for temperature. A rather neat feature is that both values are measured to the nearest tenth; that is, to one decimal place.

Unfortunately, if you poke around the Web, you'll quickly discover that there are more questions than answers concerning this device. Part of the reason for this confusion is that it spits out the readings digitally using a non-standard protocol. Another major problem for English speaking experimenters is that the datasheet (originally in Chinese) has been poorly translated and more often than not leaves you scratching your head.

Then, there's the problem of the numerical format of the readings. This is not addressed in the datasheet and demands a bit of detective work at the bench.

A few people have managed to put all the pieces

together and get it percolating in the Arduino or C languages, often employing built-in timers or more exotic aspects of microcontrollers.

Can the DHT22 sensor be made to work in the more beginner-friendly Basic language, say on a commonplace PIC, and without reference to complex hardware features? Yes, indeed!

This article lays bare these secrets and demystifies the application of the DHT22. In particular, we'll:

- Use the common and inexpensive PIC16F88 microcontroller to drive it.
- Program it in the free and easy-to-use Great Cow Basic language. (Refer to my article in the November 2012 issue which explains this awesome software.)
- Avoid timers, capture/compare modules, interrupts, and other complicated notions.
- Make it work with ordinary fixed point arithmetic (no floating point routines needed).
- Test it all with a remarkably simple LCD breadboard rig.

## How to Take a Reading

Let's see if we can first make sense of the communication protocol. Begin by looking at the schematic in **Figure 1**. As indicated there, the DHT22 is a four-pin device; +5V is applied to pin 1, while ground is pin 4. Pin 3 is a "no-connection" and simply ignored. Pin 2 is where the magic occurs.

This single pin establishes a two-way conversation with the PIC16F88. Obviously, this is going to be serial communication, but it follows a proprietary protocol — one you've likely never seen before.

There will be five bytes transmitted to the PIC. The first two give the relative humidity, and the next two give the temperature. The last byte is a checksum used to confirm everything went okay. We'll look more closely at how to interpret these five bytes in just a moment, but for now let's presume that a string of 40 bits (five eight-bit bytes) is going to shoot along pin 2 to port line A.0

of the PIC16F88. Referring again to the **schematic**, A.0 appears at pin 17 of IC1 and can be configured either as an input or output. We'll assume it's an input when first powered on, with resistor R1 acting as a pull-up.

To request a reading, port line A.0 is made an output and then pulled low for 18 milliseconds. After this fairly lengthy time, the line is pulled high again but for a much shorter 40 microseconds. This sequence then awakens the DHT22 sensor from its idling, low current state. The PIC gets ready to listen to it by making port line A.0 an input again.

The DHT22 responds with an acknowledgement, indicated by the following signals. The sensor now has control of A.0 and pulls it low for 80 microseconds. The firmware in the PIC can easily monitor this period and if things run long, a timeout is declared and some error-handling can be invoked.

Okay, let's assume everything has gone according to Hoyle so far. The DHT22 next brings port line A.0 high, again for 80 microseconds.

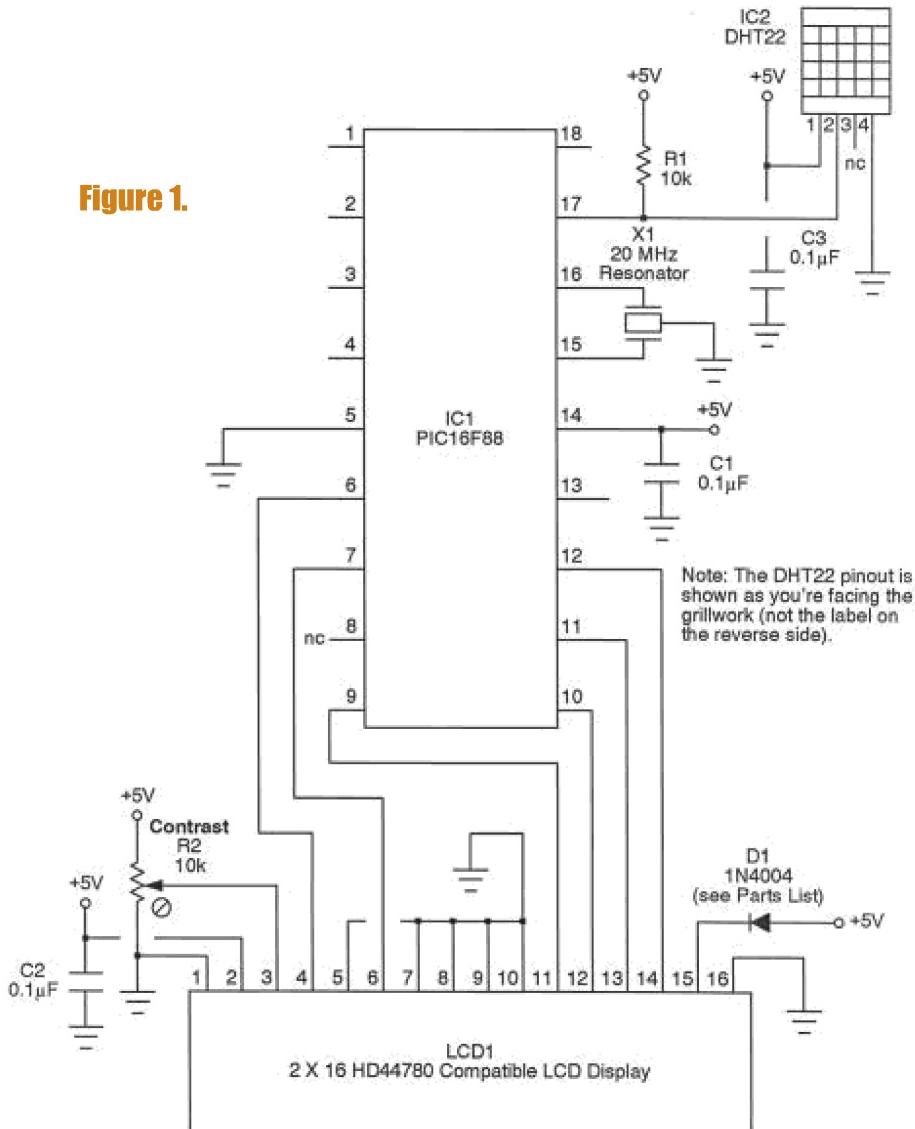
Once more, a timeout can be checked on if desired.

Thus far, the PIC16F88 has sent a request and the DHT22 has responded with an acknowledgment. The port line is still an input at this point, and the microcontroller is ready to start receiving those 40 bits that make up the five bytes. Here's how it goes:

The DHT22 drops A.0 low for 50 microseconds. You can think of this as a start signal. Now, the sensor pulls the line high again. The length of this pulse conveys the information we want. If A.0 is high for 26 to 28 microseconds, a "zero" is indicated. If it's high for 70 microseconds, then a "one" is implied. Hence, the pulse width expresses the bit status.

In everyday language: After the start signal, a short pulse represents a zero, while a long pulse signals a one. That takes care of the first bit. Now, just go back to the start of this paragraph and repeat the sequence 39 more times to get the remaining bits. Notice that port line A.0 is still an input. By the way, the bits always come in from high order to low

**Figure 1.**



order. It is convenient to store the bits in an array of bytes. Let's call it `VALUES`. In the syntax of Great Cow Basic, `VALUES(1)` and `VALUES(2)` hold the relative humidity, while `VALUES(3)` and `VALUES(4)` contain the temperature in Celsius. The checksum is in `VALUES(5)`.

One other thing; the DHT22 moves along at a fairly peppy clip, so the PIC needs to keep pace. Run the microcontroller on a 20 MHz resonator so it doesn't fall behind. On the other hand, the sensor can only update itself every two seconds, so don't query it more often than that.

## How to Interpret the Numbers

Now, comes one of the more

mysterious aspects of the DHT22: figuring out what the numbers mean. While the relative humidity is always a non-negative number, the temperature might be negative. And don't forget about the decimal fraction portion of the number. Let's see if we can untangle this mess.

Relative humidity is easy. The two bytes simply give a 16-bit representation of 10 times the relative humidity in ordinary binary notation. (The scaling factor of 10 will make more sense in a moment). In particular, if we declare an integer variable `RH`, then making the assignment:

$$RH = 256 * VALUES(1) + VALUES(2)$$

will give a result 10 times greater than the actual relative humidity. If it

isn't clear, in Great Cow Basic integers are signed 16-bit numbers.

As mentioned, the temperature may be negative. If so, the high bit of `VALUES(3)` will be set; otherwise, it's clear. Please note the following important point! The representation is **not** the usual two's complement business you might expect, but we can make it so in the following manner.

First, save that sign bit for later. Next, strip it off of `VALUES(3)`; in other words, make it a zero. That's easy to do via masking with the conjunction operator `AND`:

$$VALUES(3) = VALUES(3) \text{ AND} \\ 0b01111111$$

Then, declare an integer variable `Celsius` and carry out the assignment:

$$CELSIUS = 256 * VALUES(3) + \\ VALUES(4)$$

This variable presently holds the absolute value of 10 times the Celsius temperature. We can now factor in the plus or minus business properly. If the sign bit saved earlier was a zero, then there's nothing to do; `CELSIUS` holds the correct result. If the sign bit was a one, then let:

$$CELSIUS = -CELSIUS$$

and we're good to go. At this point, `RH` and `CELSIUS` both hold legitimate two's complement integers that are 10 times the detected values.

## Time to Print the Results

Before proceeding, we need to see how a checksum can help pinpoint erroneous results before they ever get to the LCD. Suppose we were to add up the first four bytes just received with:

$$TOTAL = VALUES(1) + VALUES(2) \\ + VALUES(3) + VALUES(4)$$

`TOTAL` can be a byte variable, since all that's needed is the least

significant byte of the sum. If this doesn't match `VALUES(5)`, then you'll know there was discombobulation somewhere and the scrambled pattern should be discarded.

Assuming everything is hunky-dory, we're ready to print the results. We don't have the luxury of floating point routines in Great Cow Basic (or in unadulterated Assembler for that matter). That's okay; we can easily deal with the decimal fraction in the following way. Remember, `RH` and `Celsius` contain properly signed integers, but 10 times too large. That's good, because if you simply divide `RH` by 10 (saving the remainder for a moment) and print the result, you'll see the whole number part.

Now, print a decimal point and follow this with the remainder just saved. Voila! There's the relative humidity and temperature — accurate to one decimal place — shining away at you.

## A Couple of Niceties

It's easy enough to convert to Fahrenheit if desired, using the well-known formula:

$$\text{FAHRENHEIT} = \text{CELSIUS} * 9 / 5 + 32$$

but you'll need a more obscure trick to get an accurate conversion out of it with integer arithmetic. The trouble lies in the division. Any remainder is unceremoniously jettisoned — this is truncation, *not* rounding.

For example, imagine the computation ended up as 56.78; you'd like this to be rounded to 56.8, but will instead wind up with 56.7 in simple integer arithmetic. Here's how to deal with the problem. Remember that `CELSIUS` contains 10 times the true Celsius reading. Before invoking the conversion to Fahrenheit, multiply by 10 so the value is now 100 times too big, yielding the modified conversion:

$$\text{FAHRENHEIT} = 10 * \text{CELSIUS} * 9 / 5 + 3205$$

I bet you were expecting to see a

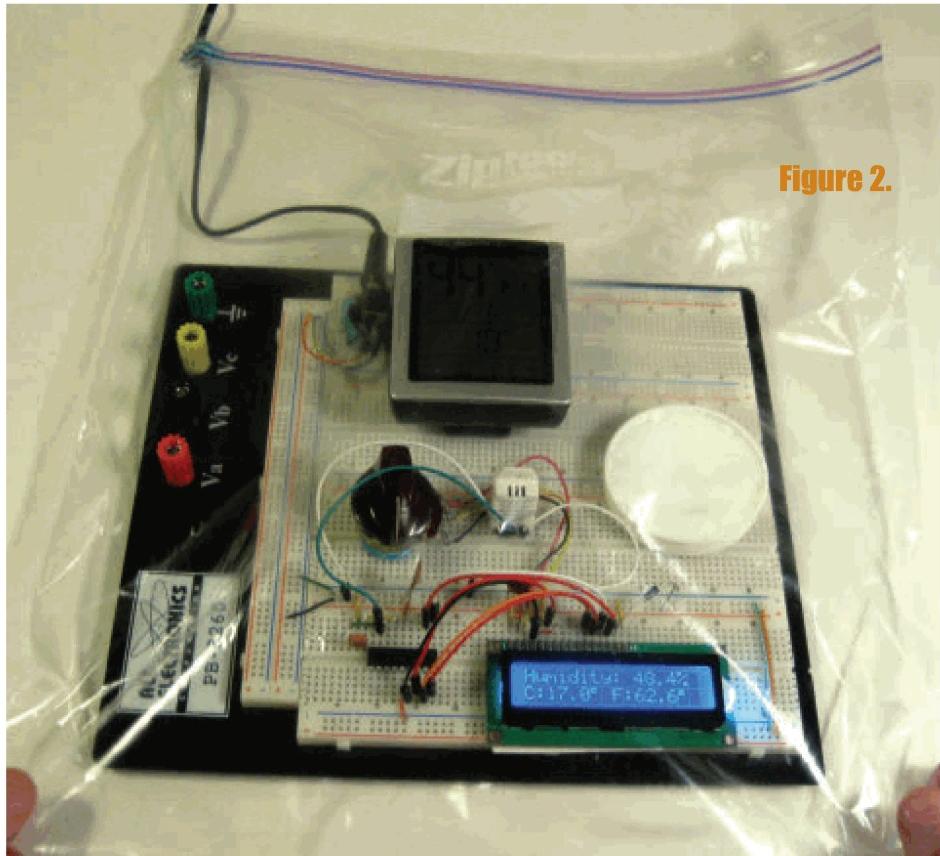


Figure 2.

3200 there (32 times 100), but by making it five units larger, we are — in effect — adding the digit 5 in the hundredths place. This will cause an overflow to the tenths place if the hundredths digit is a 5 or larger. Then, if we divide the entire thing by 10, that will dump the hundredths digit which has already served its purpose. `FAHRENHEIT` will now contain a value 10 times too big (just like `CELSIUS`) and properly rounded. If you don't believe me, try a few samples with pencil and paper. In a nutshell, we don't need no stinkin' floating point arithmetic!

You can grab the complete source code (written in Great Cow Basic) from the download link for this article. The code has been heavily commented, so you'll be able to see exactly how all of this has been implemented in an imminently practical and straightforward fashion.

Very likely, you'll want to test the relative humidity portion for accuracy. You can employ what's known as a salt box for this, or more properly here, a salt bag. **Figure 2** gives the idea. You enclose the entire circuit and sensor within a two gallon Zip-Loc bag, sealing the power

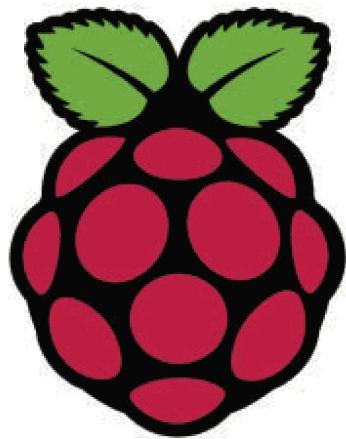
supply cable entrance with a wad of Blu Tack or chewing gum. (Blu Tack is a neat general-purpose sticky putty). Before you close up the bag, however, also include a small plastic cap filled with ordinary salt. Put a few drops of water on the salt; you want just enough so the crystals are clumpy — not soggy or runny.

Amazingly, when sealed from the outside air, the physical chemistry of such a rig will create a 75% relative humidity climate. Keep the bag poofy so there is lots of air sealed inside, and let it sit for at least 12 hours. When properly executed — and assuming your sensor is accurate — you should see the readings rise to 75%. You'll note in **Figure 2** that I also enclosed a commercial humidity gauge for comparison. I found that both ran a trifle on the low side.

That's it! I don't know why the manufacturer couldn't have made this a little easier to unravel. With a more complete and comprehensive datasheet, I bet they'd sell a lot more.

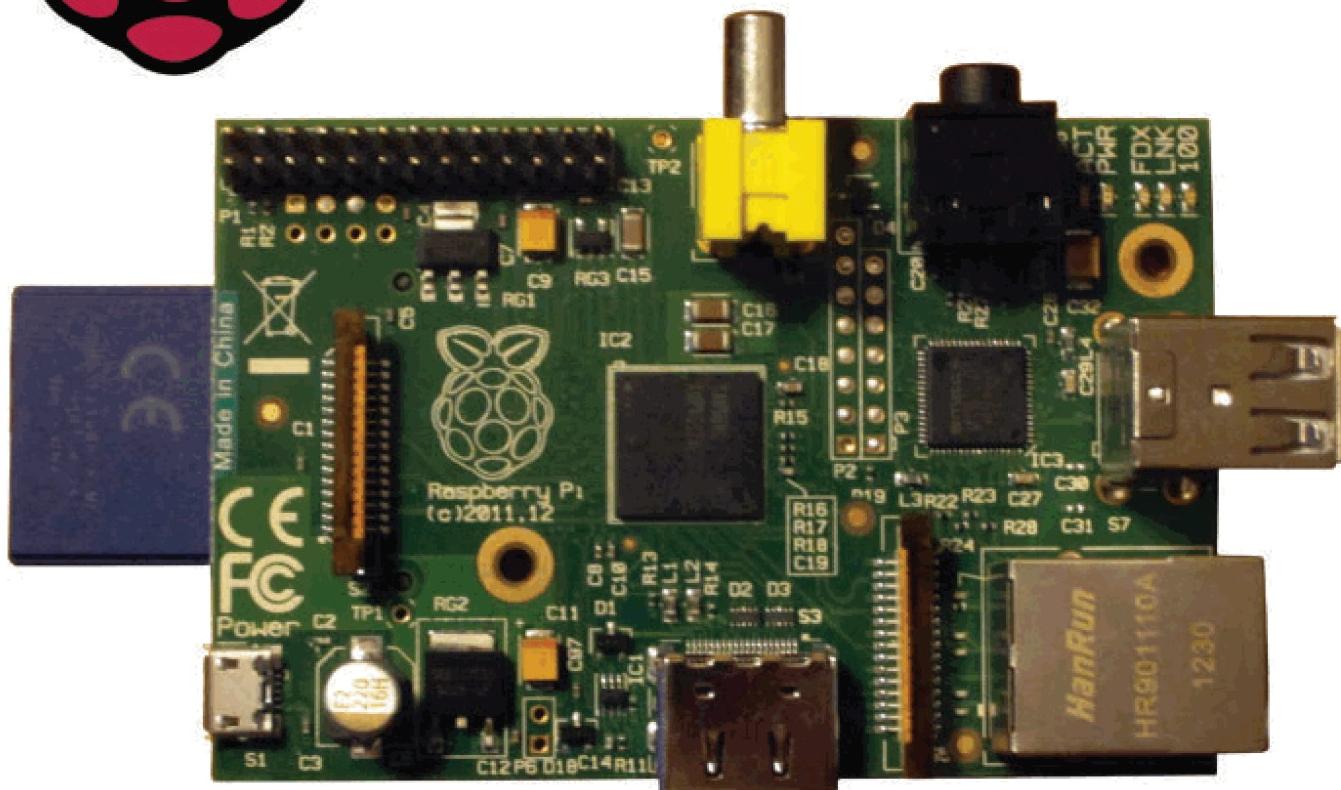
At least now, you have everything necessary to get the DHT22 up and running. Try this simple test rig and see for yourself!

**NV**



# Raspberry Pi, Anyone?

By Craig A. Lindley



**Figure 1.** The Model B Raspberry Pi. On the left is the SD memory card; top center shows the RCA composite video output; top right is where the 3.5 mm stereo audio output is located. On the right is the dual USB connector; in the lower right is the RJ45 Ethernet connector; bottom center shows the HDMI connector.

With the cost of most things continually on the rise, it is pleasing to note the price of our intelligent gadgets and that of compute power continues to fall. The cost of computing power dropped again with the introduction of the Raspberry Pi (RPi) — an ARM processor based Linux workstation the size of a credit card (see **Figure 1**). This computing marvel was developed in the UK by the Raspberry Pi Foundation (a UK registered charity) with the idea of getting students interested in computer

science by making it cheap enough for anyone to afford, and fun enough to capture their interest. The Raspberry Pi Foundation understands computers and programming are integral to the future, but noticed fewer students getting into computer science. With the RPi, they hope to rekindle the excitement over microprocessors that many of us felt in the 1970s and 1980s. I, for one, caught the computer bug at that time and haven't ever gotten over it.

**W**hile the Raspberry Pi Foundation's focus is on the educational market, there has been major demand for RPis in the DIYer/hacker community. A Google search for Raspberry Pi on the Internet will net you seemingly endless projects people are powering with RPis.

It is important to note an RPi is a bare bones single board computer built as inexpensively as possible. When you buy an RPi, you don't get a case, power supply, display, keyboard, mouse, cables, or storage device. All peripherals must be purchased separately. The idea is to connect your RPi to a USB power source, a TV set with HDMI input, a USB keyboard, and mouse. Even with the additional cost of the required peripherals, a computer system based on an RPi is still a bargain.

The Raspberry Pi Foundation has standardized on two models of the RPi hardware (**Table 1**) and have also standardized on Python as the programming language. If you don't program in Python, don't worry. Many programming languages are available for use with your RPi, including Assembler, C, C++, Java, Basic, plus various shell languages. As an added bonus, most of the software development tools for your RPi are free and open source which lowers the barrier to entry even further.

**TABLE 1. Raspberry Pi Specs.**

Feature	Model A	Model B
Suggested Retail Price	\$25.00	\$35.00
CPU	700 MHz ARM11 with hardware floating point	
GPU	Capable of 1080p video	
Memory	256 MB shared with GPU	512 MB shared with GPU
USB Ports	1	2
Video Outputs	HDMI and composite video	
Audio Outputs	Stereo 3.5 mm jack + HDMI	
Onboard Storage	SD memory card up to 128 GB	
Networking	None	10/100 Ethernet
Connectivity	8 x GPIO, UART, I <sup>2</sup> C, SPI	
Size	3.3" x 2.1"	
Power Requirement	300 mA – 1.5W	700 mA – 3.5W
Official Operating System	Raspbian version of Linux	

## Raspberry Pi verses Arduino

Many people — myself included — are currently using Arduino controllers in many of their embedded projects. While RPis and Arduinos have a lot in common, they address two different application areas. The RPi has much more computing horsepower (and hardware floating point) than any of the Arduino family, but much less directly useable I/O built onto the board. So, the RPi is a better fit for video applications, robotics, graphical applications, or anywhere there are a lot of computations needing to be done.

Arduinos, on the other hand, have lots of I/O pins which can source and sink lots of current, which makes them perfect for making things move, taking sensor measurements, data collection, driving arrays of LEDs, etc. Arduinos can perform many of the same computational tasks as RPis, but they will take a lot longer to do so.

Another big difference between an RPi and an Arduino is the idea of an operating system. When you program an Arduino, you write code and use libraries that are placed directly on top of the hardware. If you need some new functionality, you either code it yourself or find a library that provides it for you. Also, most code written for an Arduino is single threaded; your application is the only thread of execution running. You have to go to great lengths to run multiple threads on an Arduino.

The RPi, on the other hand, has a full blown, mature, multitasking, multiuser version of the Linux operating system running on it. When you write programs for an RPi, your code runs on top of the operating system and for the most part, is intentionally prevented from directly accessing the hardware. This makes for a more robust and reliable computing environment as any violation of the rules established by the operating system will cause your application/program to be terminated, but will not take the whole computer system down.

A down side of the operating system approach is the learning curve. It can take years to fully understand Linux and what it is capable of. Luckily, you don't need to understand all of Linux to put it to work. Finally, Linux is a multiuser operating system meaning that multiple people can be logged in at the same time, and each can be doing unrelated, meaningful work without knowledge of each other. By extension, this means your RPi can support many simultaneous users if your application(s) require it.

Arduinos and RPis both use the concept of shields to provide additional hardware features not found on the basic devices themselves. While Arduino shields plug directly onto the Arduino printed circuit board (PCB), the RPi equivalent is attached with a ribbon cable. Since Arduinos have been around longer, there are more shields available for it than for RPis but this situation is quickly changing. Soon there will be shields available for both

platforms that perform just about any function you can dream up.

**Table 2** provides a basic comparison between the Raspberry Pi and the Arduino families of computing devices.

**TABLE 2. Raspberry Pi vs. Arduino.**

Feature	Raspberry Pi	Arduino
<b>Suggested Retail Price</b>	~\$25 to \$35	~\$22 to \$65
<b>CPU</b>	700 MHz ARM with hardware floating point. Overclocking can increase performance.	ATMega Family with clock speeds of 8 MHz or 16 MHz. Software floating point only.
<b>GPU</b>	Built in	None
<b>Memory (RAM)</b>	256 MB or 512 MB	2K to 8K
<b>USB Ports</b>	1 or 2	1
<b>Video Outputs</b>	HDMI and composite video	None
<b>Audio Outputs</b>	Stereo 3.5 mm jack + HDMI	None
<b>Onboard Storage</b>	SD card up to 128 GB	32K to 256K Flash
<b>Networking</b>	None/10/100 Ethernet	None
<b>Connectivity</b>	8 × GPIO, UART, I <sup>2</sup> C, SPI	Up to 54 GPIO, 10-bit ADC, USART, TWI, SPI
<b>Size</b>	3.3" x 2.1"	Various sizes from postage stamp size to 2.1" x 4.0"
<b>Power Requirement</b>	1.5W to 3.5W	>=0.5W depending upon loads driven
<b>Official Operating System</b>	Raspbian Linux	No operating system

**NOTE:** The Arduino Duo has been left out of this comparison because it is ARM instead of ATMega based.

## Configuring Your RPi

What I hope to do in this article is to show you how to bring up a brand new RPi so you can start experimenting with it. You will need the following:

1. A Raspberry Pi Model A or B.
2. A USB power supply/charger capable of 500 mA or more with USB cable.
3. An SD memory card (and card reader/writer) that is at least 2 GB in size.
4. A monitor or TV with an HDMI input.
5. A USB keyboard and mouse. It is best if both of these devices work through a single USB connection.
6. A network your RPi can connect to.

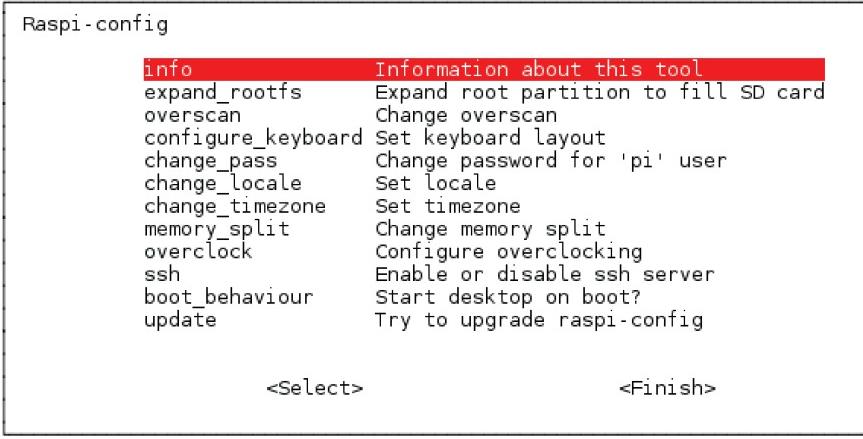
The first step in the process is to download the latest Raspbian Wheezy version of Linux from [www.raspberry](http://www.raspberry)

[pi.org/downloads](http://pi.org/downloads) and transfer it to your SD memory card. How this is done depends on the type of computer you are using. Detailed instructions for Windows, Mac OSX, and Linux are available at [elinux.org/RPi\\_Easy\\_SD\\_Card\\_Setup](http://elinux.org/RPi_Easy_SD_Card_Setup).

**SD\_Card\_Setup.** With the operating system on the SD card, insert the SD card into your RPi, connect the monitor, keyboard, mouse, Ethernet cable, and power supply. Your RPi should boot up when power is applied, and in the process you should see the boot messages racing past on your monitor.

Once the initial boot completes, the RPi configuration program **raspi-config** automatically runs; refer to **Figure 2**. From here, you set your initial configuration and (in a sense) Americanize your RPi. Remember the RPi is a product from the UK, so initially was configured for UK users. Each of the provided menu items are described in **Table 3** and suggest how you might want to set each one. If you don't understand what these configuration items do, don't worry. Just follow my lead. Use the keyboard arrow keys to move through the menu items and the return/enter key to select the highlighted one.

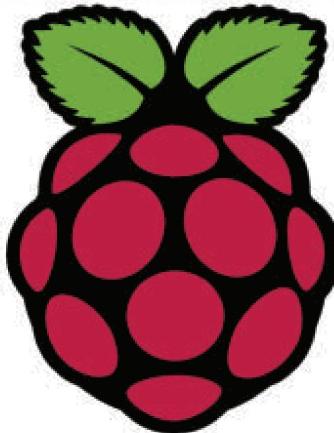
If you made changes to the defaults, you will be asked to reboot in order for them to take effect. Do so now, if necessary. When your RPi comes back up, it will be running with the configuration changes you just made. If you ever want to change the configuration again, run **sudo raspi-config** from a shell.



**Figure 2. The raspi-config screen.**

**Table 3**

Menu Item	Short Description	Long Description
Info	Information about this tool	You can skip this as it just provides information about raspi-config.
expand_rootfs	Expand root partition to fill SD card.	The Raspbian software requires about 2 GB of space on the SD memory card. Running this menu item allows your RPi to use all available space on the SD card if you use a larger SD card. Do this if you are using an SD card larger than 2 GB.
overscan	Change overscan	If you see black borders around the sides of the display when running the graphical desktop, you can disable overscan with this menu item. In most cases, this will clear things up.
configure_keyboard	Set keyboard layout	By default, a Generic 105-key (Intl) PC keyboard is selected. If you cannot find your specific keyboard on the long list, choose Generic 101-key PC. You'll be asked two more questions and you should probably answer, "The default for the keyboard layout" and "No compose key."
change_pass	Change password for 'pi' user	All RPis start out with the same user/password. If security is important for your application, you should change the password for the pi user.
change_locale	Set locale	A locale is a set of parameters that defines a user's language, country, and special preferences a user wants to see in their user interface. The default is en_GB.UTF-8 UTF-8. Find this on the list and deselect it by hitting the space bar. Next, find the US locale en_US.UTF-8 UTF-8 and select it.
change_timezone	Set timezone	Find your timezone and select it.
memory_split	Change memory split	Leave this alone unless you know exactly what you are doing.
overclock	Configure overclocking	RPIs were designed to run at a 700 MHz clock rate. It has been found that overclocking can be used to provide higher performance but with some risk of doing damage. I always choose Modest overclocking which increases the clock rate to 800 MHz but doesn't increase the voltage to the processor. Use at your own risk.
ssh	Enable or disable ssh server	Enable ssh if you plan on logging into your RPi remotely.
boot_behaviour	Start desktop on boot?	Select this menu item and then select Yes if you would like your RPi to boot directly into the graphical desktop. Otherwise, you will interact using a shell/command line interface.
update	Try to upgrade raspi-config	I suggest you don't do this yet as we will be updating all the Raspbian software shortly.

**Figure 3. RPi's graphical desktop.**

2. Log in directly using an attached USB keyboard, mouse, and monitor, and start the graphical desktop by typing **startx**. The RPi's graphical user interface is similar to Windows. Take a look at **Figure 3**.

3. You can log in to your RPi remotely using **ssh** from a remote computer. Say, for example, the IP address of your RPi is 192.168.0.13 (the IP address can be seen in the boot messages). From a shell/command line on your remote computer, you would log in with **ssh pi@192.168.0.13**, and you would then be asked for your password ("raspberry").

4. Lastly, you can use the power of XWindows and redirect your RPi's desktop to your remote computer. How this is done depends on what type of computer you are using (there isn't space here to adequately describe all the possibilities). Google *Raspberry Pi remote access XWindows* and you will find the information you need.

To shut down your RPi system, you can type **sudo shutdown -h now**. Note, it is important to shut down your RPi before you remove power so that all data will be correctly written to storage.

## Interacting With Your Raspberry Pi

Once configuration of your RPi is complete, you have numerous ways of interacting with it. You can:

1. Log in (user "pi" — password "raspberry") directly using an attached USB keyboard and monitor, and interact via the bash shell's command line.

## Resources

The Raspberry Pi Foundation  
[www.raspberrypi.org/about](http://www.raspberrypi.org/about)

*The MagPi* — a free Raspberry Pi magazine  
[www.themagpi.com](http://www.themagpi.com)

An introduction to simple Linux commands  
[http://elinux.org/CLI\\_Spells](http://elinux.org/CLI_Spells)

Craig can be contacted at [calthjh@gmail.com](mailto:calthjh@gmail.com).

## Software Update

To complete the installation/configuration process for your RPi, you should update the installed software to the latest version possible. Even though you started with the newest Raspbian release, many changes have been made to components of this version since it was made available to the public.

Directly from a shell or using the LXTerminal window

on the desktop, execute the following series of commands:

```
sudo apt-get -y update  
sudo apt-get -y dist-upgrade
```

This will cause your RPi to find, download, and install the latest versions of all of the component parts of the Raspbian software. With this, your RPi is up to date.

## A Family Friendly Development Platform

It turns out the only HDMI display I had in my home was the family's only TV set. While using the TV as a monitor was fine for a while, I needed a longer term solution. That is when I discovered the AT&T lapdock (lapdock) for the Motorola ATRIX 4G smartphone. While this discontinued product was built to provide a laptop computer interface to a smartphone, it turns out to work great with a Raspberry Pi. Consider the lapdock's features:

- A high resolution 11.6" HDMI monitor.
- A full keyboard.
- A large touchpad.
- A built-in USB hub with two external USB 2.0 ports.
- Stereo speakers.
- Internal rechargeable battery that provides up to eight hours of power.
- An external power supply.
- A super thin, sleek design that weighs just 2.4 pounds.

The best thing about the lapdock was I was able to buy it for \$50 online which is a lot of functionality for my money. Of course, since the lapdock was not designed for the RPi, it requires a bit of effort to use. Specifically, the lapdock has two connections we have to deal with: a male micro USB connector and a male micro HDMI connector. On the RPi, the HDMI connector is a full sized female connector and the USB connections are normal sized female connectors.

The HDMI interface is taken care of by a HDMI male to micro HDMI female adapter I found on DealExtreme for \$4.10. Unfortunately, I wasn't so lucky on the USB side of things. I needed a short USB cable with a female micro USB connector on one end and a full size male connector on the other. I ended up buying two cables with the required connectors, cutting them apart, and then soldering the two cables together.

**Figures 4** and **5** show what the finished configuration looks like. Normally, I connect the RPi to the lapdock with the HDMI adapter and my custom cable. I then plug my wireless adapter into one of the USB ports on the lapdock, and sometimes a Flash drive into the other.

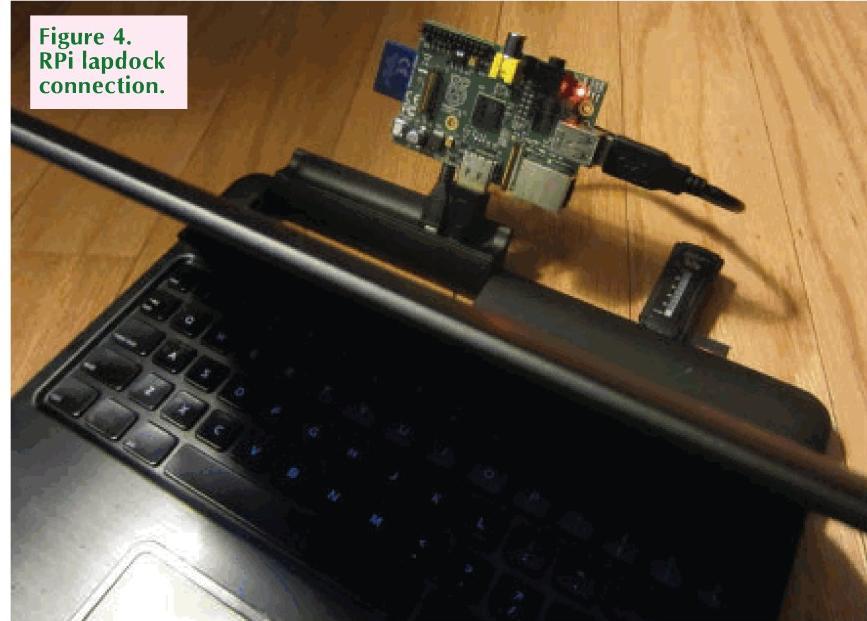


Figure 4.  
RPi lapdock  
connection.

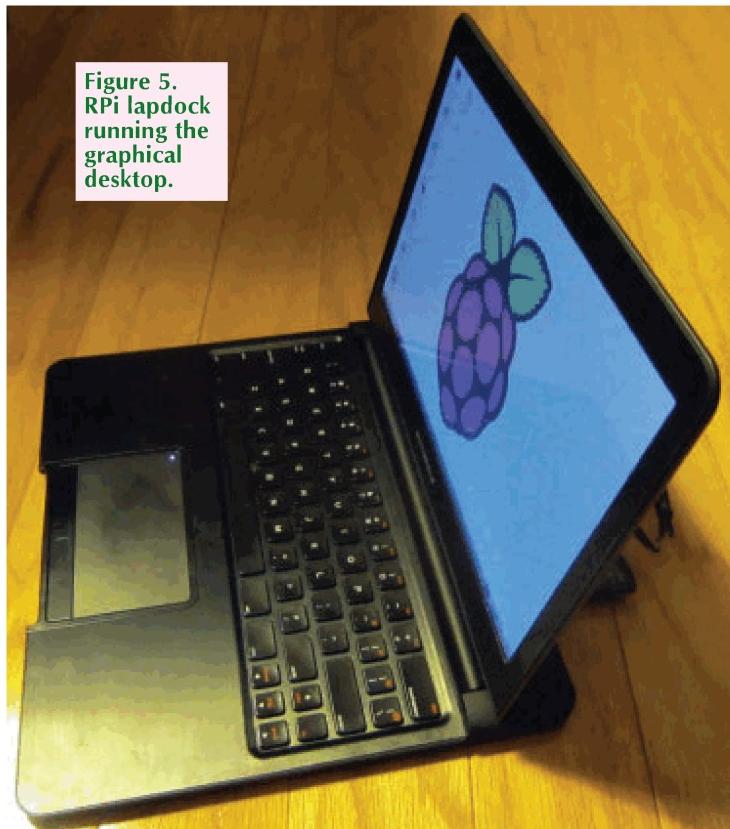


Figure 5.  
RPi lapdock  
running the  
graphical  
desktop.

## A First Application

If you followed the directions given in this article, you probably have a working RPi that you are now wanting to do something with. For your first application, how about a simple web server that can deliver multimedia content (images, videos, text, music files) on your local area network. Would you be impressed if I told you this can be done with just one line of code? Try this:

1. From a shell window, create a subdirectory off of your home directory; something like **website**, for example. Use the following command: **mkdir website**.
2. Copy the files **index.html** and **underconstruction.jpg** available at the article link into this new directory. You can either use the **scp** command to copy the files between machines, or copy the files to a USB Flash drive, then connect it to your RPi and copy the files from there.
3. Change to your new directory using the command **cd website**.
4. Execute the following one line command: **python -m SimpleHTTPServer**.
5. From a computer on your local network, hit port 8000 on your RPi. If your IP address is 192.168.0.13, for example, in your browser's address bar type **http://192.168.0.13:8000**.

If all is well, you should see the image in **Figure 6**. You now have a functioning web server to play with.

Nuts and Volts Magazine  
from the article Raspberry Pi Anyone ?  
by  
Craig A. Lindley



Congratulations your website is up and running.

You can now add your content and link to it via this index.html page.

Figure 6. Simple webserver home page.

## Conclusion

The Raspberry Pi represents a breakthrough in low cost computing power. It is a nice platform for learning about computers and Linux, as well as for multimedia and other computing/math/graphics intensive applications. I hope the Raspberry Pi Foundation succeeds in its quest to bring more people into computer science as it is a great career to have; at least it has been for me. Next time, I will show you how to turn your RPi into an Internet radio and music file player. Until then, have fun with your new piece of Raspberry Pi! NV

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# SMILEY'S WORKSHOP

#56

C PROGRAMMING - HARDWARE - PROJECTS

Part 3

## ARDUINO PROTO SHIELD ALARM CLOCK

Last month, we looked in detail at the Arduino alarm clock software on the PC side. Then, we looked at how date and time data are handled on PCs and microcontrollers. Finally, we began looking at the Arduino side of the software. This month, we will dig deeper into the software.

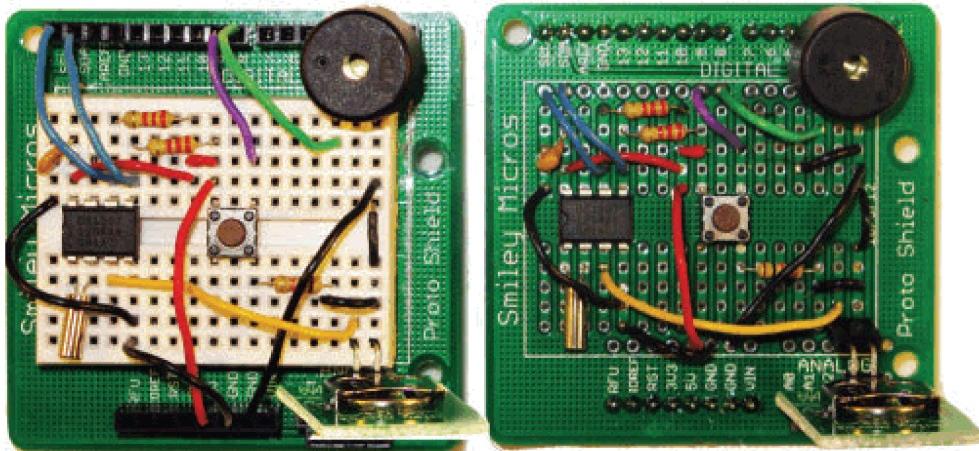


FIGURE 1. Proto shield alarm clock on breadboard and PCB.

### THE ALARM DATA

As mentioned, last month we looked at how the dates and times are stored on the PC and began to look at how they are stored on microcontrollers. Since we are using the RTCLib library for the DS1307, we will use some of that library's conventions for storing dates and times. As we saw back in Workshop 48, the DS1307 RTC (real time clock) keeps the dates and time in 10 bytes of binary coded decimal numbers. The RTCLib provides a way to convert that into Unix time, which is a 32-bit number. So, we can store it in four bytes.

We also have several other parameters associated with each alarm including the type of alarm, if the alarm is set, and if the alarm has tripped. We store these latter three pieces of information in three variables, each being one byte.

So, the total data for each alarm is seven bytes, which is shown for *alarm 1* as follows:

```
uint8_t alarm1_dt1; // first 8-bits of the 32-bit unix datetime
uint8_t alarm1_dt2; // second 8-bits of the 32-bit unix datetime
uint8_t alarm1_dt3; // third 8-bits of the 32-bit unix datetime
uint8_t alarm1_dt4; // fourth 8-bits of the 32-bit unix datetime
uint8_t alarm1_type; // the type of alarm
uint8_t alarm1_is_set; // is the alarm set?
uint8_t alarm1_is_trippled; // has the alarm tripped?
```

Since we have five alarms, this pattern is repeated five times giving us 35 bytes to store. Fortunately, the Arduino has a simple EEPROM library that we can use for this. This library has three functions that let us write, read, or clear any byte in the EEPROM. To keep things simple, we will use a *write\_alarms()* and a *read\_alarms()* function that will write or read all five alarms at one go. The *write\_alarms()* function follows this pattern:

```
void write_alarms(){
    EEPROM.write(0, alarm1_dt1);
    EEPROM.write(1, alarm1_dt2);
    EEPROM.write(2, alarm1_dt3);
    EEPROM.write(3, alarm1_dt4);
    EEPROM.write(4, alarm1_type);
    EEPROM.write(5, alarm1_is_set);
    EEPROM.write(6, alarm1_is_trippped);

    // alarms 2,3, and 4

    EEPROM.write(28, alarm5_dt1);
    EEPROM.write(29, alarm5_dt2);
    EEPROM.write(30, alarm5_dt3);
    EEPROM.write(31, alarm5_dt4);
    EEPROM.write(32, alarm5_type);
    EEPROM.write(33, alarm5_is_set);
    EEPROM.write(34, alarm5_is_trippped);
}
```

The *read\_alarms()* function follows this pattern:

```
void read_alarms(){
    alarm1_dt1 = EEPROM.read(0);
    alarm1_dt2 = EEPROM.read(1);
    alarm1_dt3 = EEPROM.read(2);
    alarm1_dt4 = EEPROM.read(3);
    alarm1_type = EEPROM.read(4);
    alarm1_is_set = EEPROM.read(5);
    alarm1_is_trippped = EEPROM.read(6);

    // alarms 2,3, and 4

    alarm5_dt1 = EEPROM.read(28);
    alarm5_dt2 = EEPROM.read(29);
    alarm5_dt3 = EEPROM.read(30);
    alarm5_dt4 = EEPROM.read(31);
    alarm5_type = EEPROM.read(32);
    alarm5_is_set = EEPROM.read(33);
    alarm5_is_trippped = EEPROM.read(34);
}
```

## WHAT ABOUT TIME ZONES (TZ) AND DAYLIGHT SAVINGS TIME (DST)?

Oh bother! Both TZ and DST are a pain for time keeping. They are political constructs and vary all over the place. Don't get me wrong here; they are good ideas for people and productivity, but for keeping track of time – not so much. I noticed the problem for our particular application when I suddenly saw that my Arduino alarm clock had lost an entire hour overnight – according to the PC, anyway.

Of course, all the clocks in my house had to be set back manually – that I'm used to – but what about my desire to be able to keep track of time on the Arduino automatically and have it cross-checked by plugging it into a PC and running the C# alarm clock application?

Then, it occurred to me that I might visit relatives three time zones to the west, so if I plug my alarm clock into my PC, is it going to be three hours off? How in the heck am I supposed to use the PC to set the time and keep it calibrated?

It just so happens that the C# DateTime class has all sorts of features for dealing with this on the PC, which gets its time base off the Internet and is pretty darn accurate. If we keep the Arduino plugged into a PC so that it will know when you change TZ or DST, then why even bother with the RTC module? Should we build some sort of comprehensive Arduino library to help us keep track of changes in TZ and DST? Sounds like a lot of work to me – especially when we have to factor in that different political entities deal with this in different ways. This might be worth the effort if our purpose here is to create some kind of universal stand-alone clock, but that isn't our goal.

Your bedside alarm clock probably doesn't know what TZ it is in or the state of DST, so you set those things manually. Should an inexpensive Arduino based alarm clock be any different? Maybe, but I want to keep it simple since our main goal is to learn about time keeping on a microcontroller, and the secondary goal is to build software for letting us track time and use the microcontroller to do things at specific intervals.

Fortunately, lots of folks have faced this problem before and use UTC (Coordinated Universal Time Code). [No, that isn't a misprint. The acronym disagreeing with the name is the result of an argument between English speakers who wanted to use CUT and French speakers who wanted to use TUC, with the usual result that nobody got what makes sense.] UTC time is the inheritor of the GMT or Greenwich Mean Time which was the British Empire's way of saying that we'd set all our clocks right there at the Royal Observatory in London and everybody else will bloody-well like it.

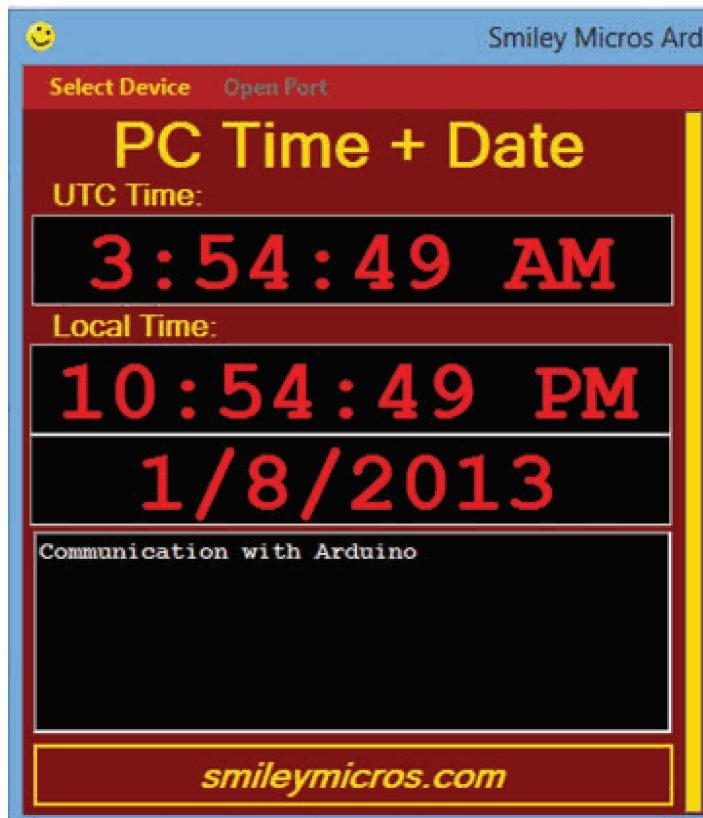


FIGURE 2. Added UTC time to PC application.

```

// Date Time module for the time keeping functions
//
// Most of the DS1307 timekeeping items and concepts were taken from
// RTClib provided by Jean-Claude Wippler of www.jeelabs.com
//

// Initialize the I2C communications and the DS1307 Real Time Clock
void initializeDS1307RTC()
{
    Wire.begin(); // initialize the I2C communications
    RTC.begin(); // initialize the DS1307 real time clock
    /setDateTimeToPC(); // get the current date and time from the PC

    // Initial alarm state is off
    alarm1_set = 0;
    alarm2_set = 0;
    alarm3_set = 0;
    alarm4_set = 0;
}

```

FIGURE 3. Arduino code modules.

If you choose to use UTC, then you can apply conversions to get the locally accepted time in your politically specific TZ and DST. So, we are going to change our software to use UTC. The modification of the C# code for the PC side of the Arduino alarm clock application is minor:

```
labelUTCTime.Text = DateTime.Now.ToUniversalTime().ToString("T");
```

So, to help us keep track, I've added an additional window so we can see UTC and local time on the PC side, while only displaying UTC on the Arduino side — see **Figure 2**.

## HOW THIS CODE IS ORGANIZED

Using the external real time clock module (DS1307) to keep track of dates and times is the core of our project. However, there are several other things we need to do in the software that are more general housekeeping type activities in order to have a functioning alarm clock.

These include receiving commands from the PC that we will use to set the date, time, and alarms, and how we will process those alarms (which includes the types of audible signals we can emit and how we will process a user button press). Plus, of course, there is the usual Arduino front end.

All together, this gives us four fairly separable parts of the software:

1. Alarm\_Clock – Arduino front end
2. Commander – PC command functions
3. Date\_Time – DateTime functions
4. Process\_Alarms – Process alarm functions

We could keep all this code on a single 'page' module like we've done before, but this project has a LOT of code and some of it — such as the command processing section — is generic enough that we might want to keep it separate. This gives us the added benefit that by making it generic, we can easily port the techniques for some other project that needs a command processor that communicates with a PC. So, for this project, it makes sense to divide our code into four separate modules, following the list shown previously.

The Arduino has a feature where you can keep separate modules in a single project. Each module is available in the editor through tabs at the top of the editor as shown in **Figure 3**.

Let's discuss the code in each module as separate items.

## ALARM CLOCK – ARDUINO FRONT END

The Alarm\_Clock module begins with variable definitions and initializations, and by defining constants. These are used by the pushbutton debounce functions to initialize DateTime structures, to declare alarm states, and to set up PC communication constants, variables, and arrays. Of particular interest is the `#define DEBUG` definition. If this is left as is, then throughout the code debugging messages will be printed to the serial port. For example, in the Arduino setup function we have:

```
#if defined(DEBUG)
  Serial.println("DEBUG mode");
  pinMode(7, OUTPUT);
  for(int i = 0 ; i < 5; i++){
    digitalWrite(7, HIGH);
    // turn the LED on (HIGH is the voltage level)
    delay(250);           // wait for 1/4 second
    digitalWrite(7, LOW);
    // turn the LED off by making the voltage LOW
    delay(250);           // wait for 1/4 second
  }
#endif
```

So, when the Arduino starts up it will send the 'DEBUG Mode' message to the PC and it will blink the LED five times. Once you are confident that the code works as you want it to, you simply put '//' in front of the define as follows: `//#define DEBUG`. Now, `DEBUG` will not be defined and the debug messages will not be printed. I've left this in the final code since I assume this alarm clock software will be heavily modified by folks wanting to apply it to specific situations, such as using it in a data logger.

The Arduino `loop()` function holds three key concepts for this program. First, it processes messages from the PC by checking to see if any serial characters have arrived, and if so, it calls the `loadMessageArray()` function that deals with PC messages.

Second, it processes alarms by checking to see if the `check_alarm` flag has been set (by a timer interrupt). If the flag is set, then it checks to see if any alarm is active. If one is, then it calls the associated function for that alarm. After checking the alarms, the flag is set back to 0, allowing the `loop()` to loop until the next time the timer sets the flag. This flag is set once per second.

You might think it would make sense to just check each alarm on each pass of the loop, but doing that will quickly overwhelm the system. So, checking them once per second leaves time to do other things in the `loop()`. Alarms are on one-second boundaries, so it makes little sense to check them more often. One second might not seem like much, but your Arduino will do nearly 16 million instructions in a second. So, it has lots of time to get other things done between possible alarm changes.

Third, the loop checks to see the state of the pushbutton. It uses a debounce method to make sure the button is really pushed, and that we aren't accepting glitches or button bounces as press release sequences. The debounce button state — either on or off — is shown on the LED.

## COMMANDER – COMMAND FUNCTIONS

The Commander module is a generic command processor for receiving commands from a PC application, like the alarm clock one we discussed in some detail last month. This application structures command strings that it then sends to the Arduino alarm clock program, which interprets and acts on those commands.

The command parser is rather simple-minded and uses a series of case statements to analyze the incoming message. For our particular application, we terminate each message with an exclamation mark '!' character and separate parts of the message with a comma ',' character. These are defined at the top of the Alarm\_Clock module under TERMINATOR (the '!') and SEPARATOR (the ','). You can change them as needed for your particular application.

In the main Arduino `loop()` function, the `loadMessageArray()` function in the Commander module is called. It loads the message array with the most recent characters from the PC and then checks for the terminator symbol. If it is found, it then calls the `parseArray()` function. If it isn't found, it returns and the `loop()` continues with the next function. This allows messages to come in piecemeal, and lets the Arduino do other stuff while the message is coming in. Let's look at the `parseArray()` function:

```
void parseArray()
{
  int i = 0;
  int j = 0;
  while( (messageArray[i] != TERMINATOR) && (i < MAX_MESSAGE) )
  {
    while( (messageArray[i] != SEPARATOR)
    {
      commandArray[j++] = messageArray[i++];
    }
    commandArrayCount = j;
    parseCommand();
    j = 0;
    i++;
  }
  messageArrayCount=0;
  initializeMessageArray();
  // Clear the receive buffer before going back
  // to the loop()
  while(Serial.available()) Serial.read();
}
```

This function runs two *while* loops: the first guards against over-running the maximum message size and stops at the terminator; the second separates out the leading command and calls the *parseCommand()* function which runs a case statement against the command's first character. If a command has more than one character, the function called for the first command runs another case statement for the second character in the command and so on, until the full command is parsed. For example, we use two commands with the same first character: *MI* and *MO*. [These are educational examples only since they merely report to the PC that they have been called.]

The following code snippets show how this is done:

```
// Parse a command from the PC and call the
// function
// associated with the command
void parseCommand()
{
    switch (commandArray[0])
    {
        case 'A': // Set Alarm # 1 to 5
            ACase();
            break;
        OTHER CASES
        case 'M': // Minute (MI) or Month (MO)
            MCase();
            break;
        OTHER CASES
    }
}

LATER IN THE CODE:

// Minute (MI) or Month (MO)
void MCase(){
#if defined(DEBUG)
    Serial.println("MCase");
#endif
    switch (commandArray[1])
    {
        case 'I': // Minute
            MICase();
            break;
        case 'O': // Month
            MOCase();
            break;
        default:
            Serial.println("MCase Bad command
Array[1].");
            break;
    }
}

// Minute
void MICase(){
```

```
#if defined(DEBUG)
    Serial.println("MICase");
#endif
}

// Month
void MOCase(){
#if defined(DEBUG)
    Serial.println("MOCase");
#endif
}
```

There may be 'better' (more general) ways to parse commands, but this is about the simplest I know of and is sufficient for our purposes.

## DATE\_TIME – DATETIME FUNCTIONS

Last month, after discussing how dates and times are handled by computers, we decided to use Unix concepts as the basis for keeping track of dates and times. The Date\_Time module has the functions we'll need to keep the data, and to receive it from and send to the PC. Some of the functions are simple, such as:

```
void show_time()
{
    DateTime now = RTC.now();

    Serial.print("TIME");
    Serial.print(now.hour(), DEC);
    Serial.print(':');
    Serial.print(now.minute(), DEC);
    Serial.print(':');
    Serial.println(now.second(), DEC);
}
```

This function reads the RTC, loads a *DateTime* type variable with the current time, and then sends it out the serial port.

### Setting the Date and Time

It is a bit more complicated to set the date and time on the RTC using data from the PC. The PC application has the following line of code for sending the *datetime* string to the Arduino:

```
serialPort1.WriteLine("P" + _UnixTimeSpan.Total
Seconds.ToString() + '!');
```

This arrives at the Arduino as the command string: "P#####!" where all the '#' are the Unix seconds since inception (as discussed last month). The data is processed by the `setDateTimeToPC()` function:

```
void setDateTimeToPC(){
    int i;
    uint32_t myUnixTime = 0;
    uint32_t mult = 1000000000;
    for(i=1;i<=10;i++){
        Serial.print(commandArray[i]-48,DEC);
        myUnixTime += (commandArray[i]-48) *
mult;
        mult = mult/10;
        if(commandArray[i] == '-')break;
    }
    Serial.println("*\n");
    Serial.print(myUnixTime,DEC);
    Serial.println("^*\n");

    RTC.adjust(myUnixTime);
}
```

The `setDateTimeToPC` function takes these # characters and subtracts 48, thus converting the ASCII character for the number into the actual number (ASCII 48 is the character 0, so if the # is 48, then subtracting

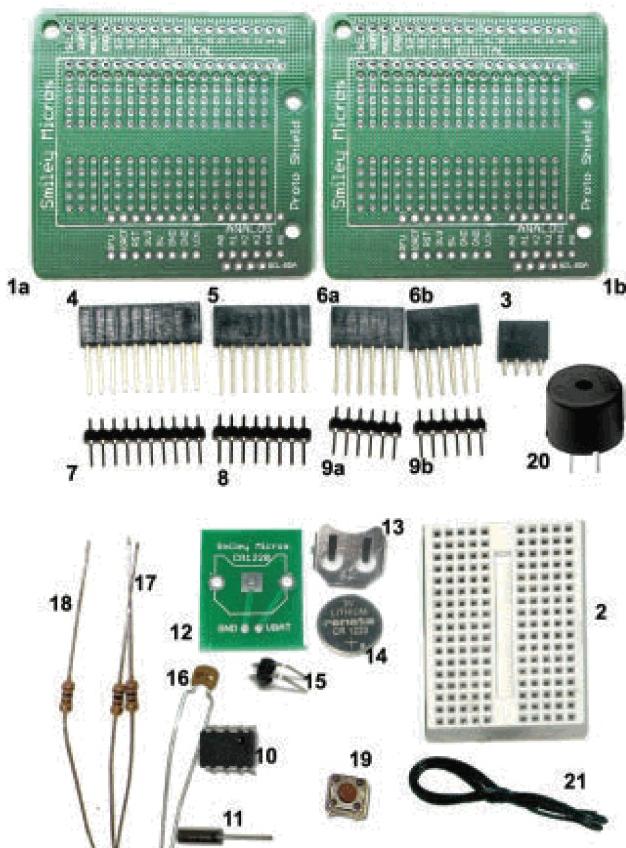
48 yields 0, and since the remaining nine digits are sequential, that means 49 is '1.' Therefore,  $49 - 48 = 1$ , and so forth.).

The function then multiplies each number by the multiplier (1000000000), and each subsequent number by the multiplier divided by 10, thus converting each character of the Unix *datetime* string into the numeric value represented by that character at that position. If this isn't clear, it might be a good idea to get a pencil and paper and follow the code presented. You'll then quickly see what is happening.

Once the character string is converted to a 32-bit number, that number is then sent to the RTC with the instruction to adjust the time to the value given.

## PROCESS\_ALARMS – PROCESS ALARM FUNCTIONS

The fourth module processes the alarm functions. However, we have run out of space again, so we will continue with this next month. Let's try not to lose track of what we are doing in the long run here. We are taking several articles to learn to do a complete Arduino-based design – both hardware and software – ending with our own custom-made (in Fritzing) alarm clock printed circuit board and robust software applications for it on the PC and the AVR. NV



## Arduino Proto Shield Alarm Clock Kit

This article is Part 3 in a series based on the Arduino proto shield alarm clock kit. This kit lets you build an alarm clock circuit on a breadboard and port that circuit to a PCB. This kit is the basis for my presentation of how to do a complete Arduino design cycle using Fritzing to go from a breadboard prototype, through schematic creation and breadboard layout, and finally producing your own printed circuit board. You can get the kit or materials that support this learning activity from the *Nuts & Volts* webstore.

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*Did you know that much of what you read in Nuts & Volts comes from readers just like you?*

A dramatic, low-key photograph of a rock star performing on stage. The performer is silhouetted against a bright, orange-yellow light, possibly from stage spotlights. They are holding a guitar and a microphone stand is visible to the left. The background is dark, suggesting a concert setting.

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# NEAR SPACE

■ BY L. PAUL VERHAGE

APPROACHING THE FINAL FRONTIER

## A SIMPLE AIRFRAME FOR A SIMPLE FLIGHT COMPUTER OR NEAR SPACE TRACKER

I've always made my own near space airframes from Styrofoam™. However, there are times I want a simple airframe that's quick to assemble. Enter an insulated lunch box. I will describe for you how I make my conversions. It was actually the Treasure Valley Near Space Program and Nebraska Stratospheric Amateur Radio (NSTAR) that introduced me to this simple airframe.



The backup tracker for this near space mission is housed inside a lunch box. Can't recognize it? It's the first module below the recovery parachute.

An airframe assembled from Styrofoam sheets has many benefits – one of them being that it's built to the exact dimensions desired. On the down side, such an airframe can be complicated to design and construct, which means they take some time to assemble. In many cases, this cost in time and complexity is justified. Just ask any satellite designer and many of them will agree.

That being said, there has also been an effort to standardize satellite airframes. One prime example of this is the CubeSat which is a 10 centimeter cube which is becoming increasingly popular with universities.

Newly formed near space groups needing a tracker or simple flight computer can begin launching sooner if they use a standardized airframe. I believe that converted lunch boxes will make a great standardized airframe for trackers and simple flight computers. That's the kind I want to discuss here.

If, however, you're interested in the design and construction of more complex Styrofoam airframes, consult Chapter 1 of my *Near Space with the BASIC Stamp* e-book. It's available at no cost from [Parallax.com](http://Parallax.com).

Discuss this article in the *Nuts & Volts* forums at <http://forum.nutsvolts.com>.

## THE NEAR SPACE LUNCH BOX AIRFRAME

Many readers use a soft-sided reusable lunch box to bring their meal to work or school. These are foam-insulated bags with zippered enclosures. Their insulation and convenient size makes them a great airframe for near space.

After beginning a doctoral program at the University of Kansas, I modified my first lunch box into a near space airframe for the university's aerospace engineering department. The result was an inexpensive backup tracker for the department's near space flights. I'm pleased with the results and feel it worked well for the near space APRS tracker.

You can build one with the following materials:

- Insulated soft-sided lunch box
- Sheet of Coroplast\*
- Thick foam rubber (one or two inches thick would be ideal)
- One inch wide woven-nylon strap\*\*
- Twelve 10-24 bolts
- Twelve 10-24 nylon lock nuts (nylocks)
- Twenty-four fender washers for 10-24 bolts
- Four heavy duty 1.5" metal split rings
- Luggage tag
- Loud piezo alarm
- Nine volt battery snap

I found that a hot knife or soldering iron is a useful tool for modifying a lunch box.

\*Coroplast is a brand of corrugated plastic sheet that's 1/8" thick. It's available from local plastic distributors and some hobby shops.

\*\*I purchased the nylon straps from a local fabric store. The store staff cut six feet of material from the roll that I brought to the store's cutting table.

**FIGURE 1.**  
One of my modified lunch box airframes.



### OVERVIEW OF THE MODIFICATION

You'll modify the insulated lunch box by first attaching four nylon straps to the sides of it. The straps let the airframe connect to a recovery parachute (above) and other modules like BalloonSats (below). Then, you'll add a Coroplast panel to the back of the lunch box to support an antenna and audio beacon.

### NYLON STRAPS

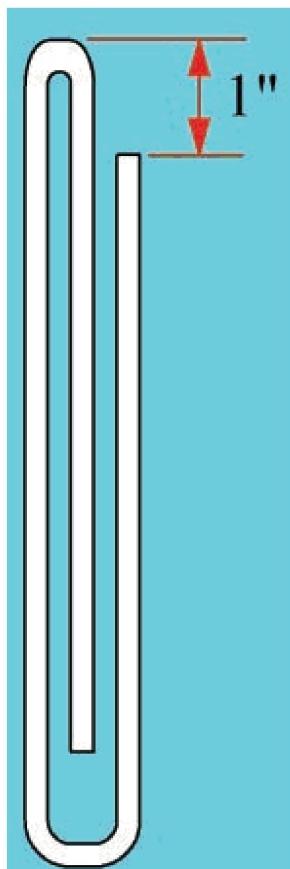
The first thing to do is attach four nylon straps to the corners of the lunch box. Since it's difficult to sew straps to the lunch box, they're bolted to it instead. Make the straps by cutting four pieces of heavy nylon ribbon or strap. The four straps are cut to the same length; for my lunch box, they are 15 inches long. If you are modifying a taller lunch box, you may need to use longer straps.

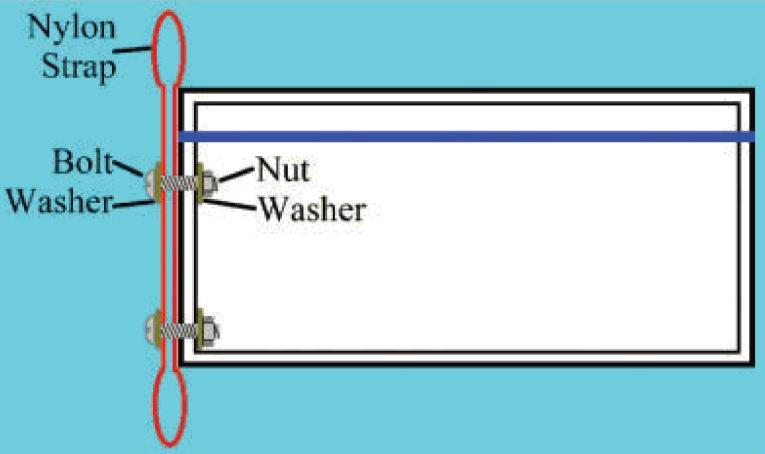
After cutting the straps, melt the cut edges of the strap with a lighter. This prevents the edges from fraying. (It takes only a small amount of melting to prevent fraying.) Next, fold a strap into thirds with an overlap that leaves a one inch loop at each end. **Figure 2** illustrates how you should fold the straps.

Take the folded strap and position it on the outside of the

lunch box and along one of the edges. Next, determine where you will place the bolts that will attach the strap to the lunch box. Note that each bolt needs two washers, and that one of the washers must fit completely inside the lunch box. This means the top washers can't be too close to the top where it interferes

**FIGURE 2.**  
You will need four of these straps with one inch loops at the top and bottom. Bolts will attach the straps to the lunch box through three layers of the nylon strap.





**FIGURE 3.** The washers add strength to the connection between the straps and the lunch box by increasing the area compressed together. Notice that the top bolt is far enough below the lid zipper so that it doesn't interfere with opening the zippered lid.

with the lunch box zipper.

In addition, the bottom washer can't be too close to the bottom where it can't fit inside the lunch box. Now, use a hot knife or soldering iron to melt two holes through the strap and lunch box.

Place a washer on a bolt and push the bolt through the bottom hole in the lunch box, with the head of the bolt on the inside. Then, line up the strap's bottom hole and push the strap onto the bolt. Put a second washer over the bolt, followed by the nylock. Don't tighten the nylock fully

at this time. Repeat a second time for the top hole. Now, tighten both nylocks.

This attaches the strap tightly to the side of the lunch box, with the nuts and bolts "sandwiching" the strap to the lunch box. Repeat these steps for the other three straps.

Next, add the split rings to the nylon straps. One split ring goes through each loop at the end (top and bottom) of the nylon strap. The rings make it easier to connect a parachute and other modules to the airframe.

## ANTENNA BOOM

The antenna boom is a sheet of Coroplast that attaches an antenna and an audio locator beacon to the airframe. The boom is connected to the back of the lunch box in the same way that the straps are connected to the sides of the lunch box.

Begin by cutting a rectangular panel of Coroplast three inches high and six inches wider than the width of the lunch box. Center it on the back, and punch four holes through it and the back of the lunch box. Then, bolt it to the lunch box using nuts, bolts, and washers, with the head of the bolts inside the lunch box.

The boom will extend beyond both sides of the lunch box by three inches. That's enough space for the antenna and the audio beacon.

The first thing to add to the antenna boom is an audio locator beacon. The audio locator beacon is a piezo alarm that produces a volume of at least 80 dB. I recommend an audio beacon like item 273-080 from RadioShack.

This alarm is great not only because it is loud running off a nine volt battery, but because it also has

**FIGURE 4.** The back of the lunch box with its Coroplast antenna boom.



mounting tabs.

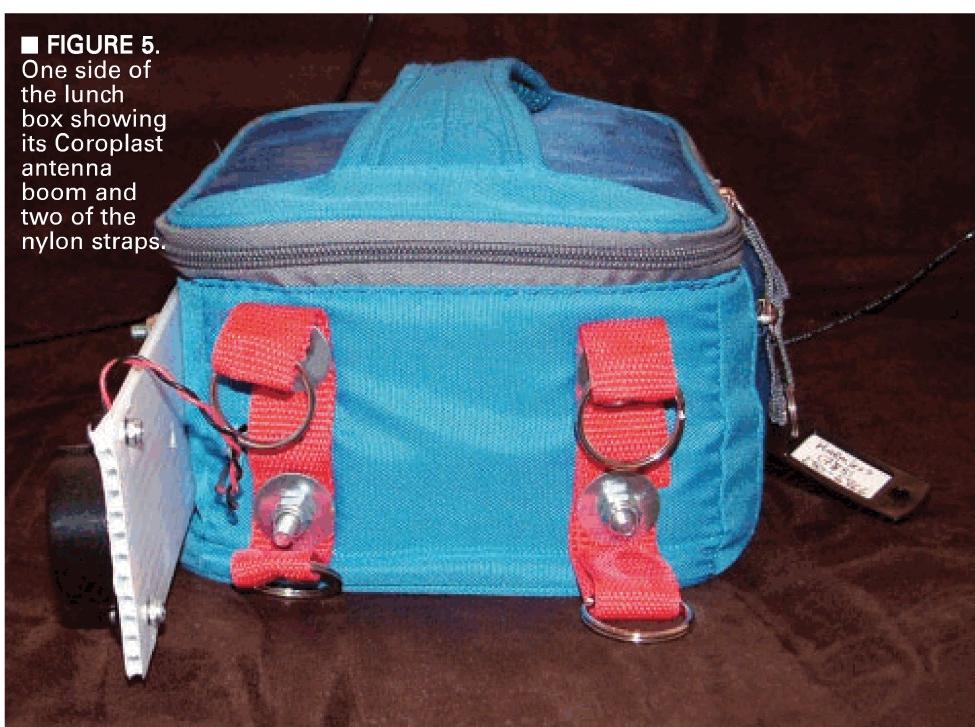
Start by soldering a nine volt battery snap to the piezo alarm leads and cover the soldered connections with heat shrink tubing. Then, use a pair of small bolts and nylocks to attach the piezo alarm to the boom.

The battery wire enters into the lunch box through a hole, so find a location for this hole in a corner of the lunch box and near the antenna boom. Cut the hole just large enough for the nine volt battery snap to push through.

Protect the alarm wires from getting snagged or pulled on by using a couple of nylon zip ties to hold the wires against the antenna boom.

Mount the antenna to the other side of the antenna boom. I strongly encourage the use of an antenna plate, and then bolting this

**■ FIGURE 5.**  
One side of  
the lunch  
box showing  
its Coroplast  
antenna  
boom and  
two of the  
nylon straps.





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to the antenna boom. Since the antenna gets exposed to the cold air of near space, don't use nylon zip ties to affix it to the antenna boom. Instead, attach the antenna plate using small bolts and nylocks. Don't make a hole in the lunch box for the antenna cable to pass into the lunch box just yet; make it after placing the radio tracker inside the airframe.

Finally, add the luggage tag to either the zipper handle or to a split ring. On the luggage tag, write your contact information. That way, if the tracker gets lost during a mission someone coming across the lunch box will know how to contact you.

## INTERIOR OF THE AIRFRAME

At least two sheets of foam rubber and a sheet of Coroplast are stacked together to fill the volume of the lunch box airframe. Measure the interior dimensions of the lunch box, and cut the foam rubber and Coroplast to size. If this stack of material is too thin to fill the volume of the lunch box, then add additional sheets of foam rubber. These additional sheets are stacked inside the empty lunch box before the other three layers.

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The bottom sheet is cushioning for the radio tracker and GPS receiver when the module lands. It also holds the battery in place. Therefore, cut out a pocket in the bottom foam rubber sheet large enough to hold the battery. Place the cutout near one edge of the foam rubber so that it is easier to insert the battery prior to stacking the radio tracker. Also, make the cutout just large enough for the battery so the fit is tight and the battery doesn't bounce around.

The second layer is the sheet of Coroplast. This is the avionics pallet and holds the radio tracker. I use nylon zip ties to attach the tracker PCB (printed circuit board) since the board isn't all that heavy. I also like to sandwich a thin sheet of foamed neoprene between the PCB and the Coroplast to fill in space between them that's created by the soldered wires and mounting hardware.

Before going any further, insert the bottom foam rubber sheet and avionics pallet into the airframe. Determine the natural place for the antenna cable to pass through the wall of the lunch box and melt a small hole through the wall.

The final top layer of foam rubber stacks on top of the radio tracker and provides cushioning for the GPS receiver.

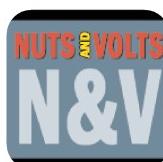
## STACKING THE AIRFRAME

Lay the battery into the bottom layer of foam rubber and connect it to the tracker. Now, stack the avionics pallet on top of the bottom sheet. Next, attach the antenna cable and the GPS module to the radio tracker. For now, let the GPS receiver dangle over the edge of the lunch box. Then, stack the top layer of foam rubber over the avionics pallet.

The GPS module is thin, so place the GPS on top of the top layer of foam rubber, making sure the antenna of the GPS is on top. In other words, make sure the GPS isn't upside down. Now, zip the lid of the lunch box closed.

The lunch box airframe is now ready for its recovery parachute and the other modules that will accompany it on its near space mission.

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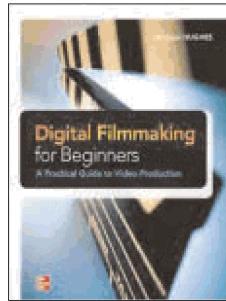
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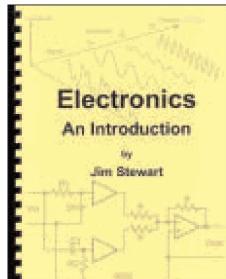
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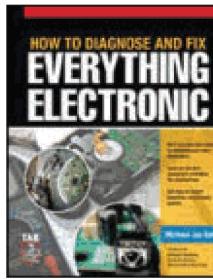
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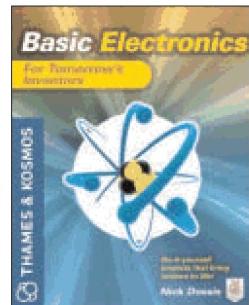


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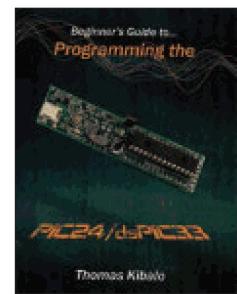


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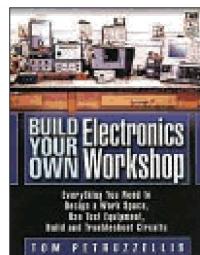


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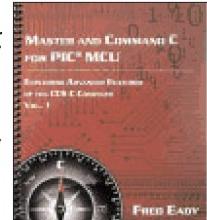
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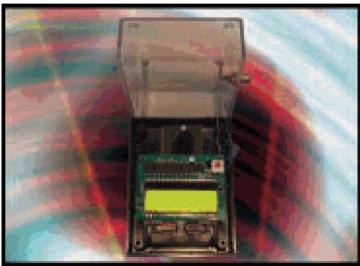
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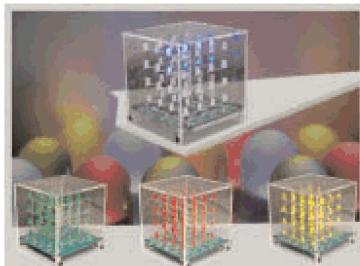
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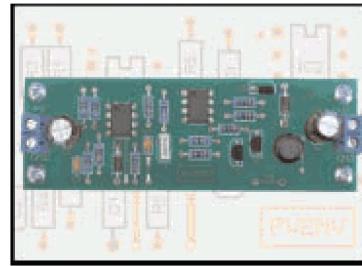


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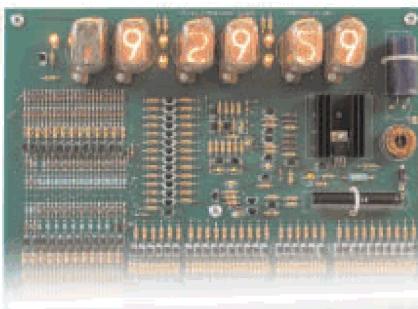
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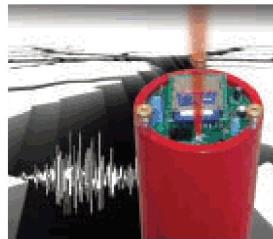
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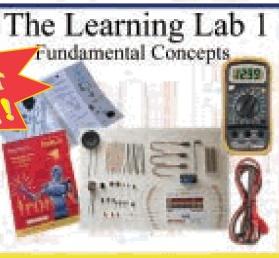


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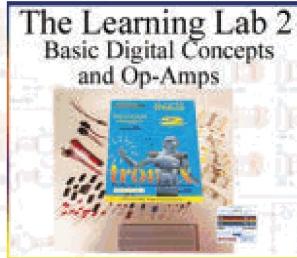


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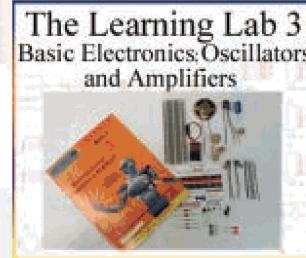
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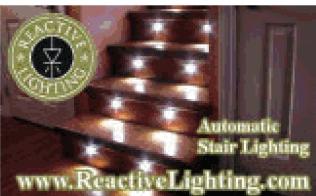
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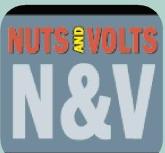
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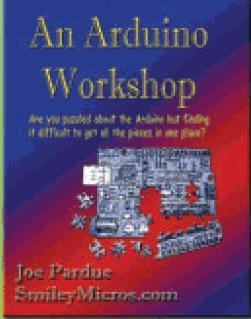
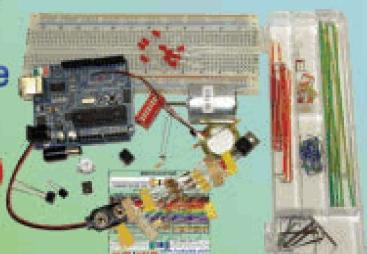
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## >>> QUESTIONS

Visit our Tech Forum online at [www.nutsvolts.com/tech-forum](http://www.nutsvolts.com/tech-forum) to view and answer new questions as they come in.

I'm building a propeller balance meter. This unit was designed and built for in-house use at Rockwell International (North American Aircraft Corp.) Columbus, OH.

There were approximately 200 additional units that were built for Rockwell's Aero Commander dealers around the late 1960s. It uses a velocity type pick-up which is what I need. Best as I can find out, it was a type MU 6-7 Pn. B 11032-1.

If anyone knows where I can get one of these pick-ups or what could be substituted, I would appreciate any help; a used or surplus part is preferred.

**#3131**                   **A. Schwedler**  
                                  Stroudsburg, PA

I lost my hearing at a very young age and have always struggled with listening to the audio out phones, computers, MP3 players, etc. When I have my hearing aids in and try to listen, it's actually worse!

I would like to build an audio amplifier with a programmable equalizer, to be connected to the 3.5 mm audio output jack. I will connect +5V separately.

The device will be connected to a PC temporarily through the USB jack for programming, and then be removed.

Here are my questions:

Is a one stage amplifier enough?

Is it better to amplify first then equalize, or equalize then amplify?

Who makes the best audio chips?

What software is needed to program the EQ?

Any suggested readings, websites, software, forums, etc.

### Specifications:

Easy to build and program using a chip like Monolithic Linear integrated circuit LA3600; [www.electronics-lab.com/blog/?tag=equalizer](http://www.electronics-lab.com/blog/?tag=equalizer).

Input voltage: 5V

Gain: ?

Equalizer: Seven band or better

Output: 3.5 mm

And for the hard way, using a DSP or FPGA to build an advanced equalizer/gain headset that could be used in any computer, phone, or MP3 player!

**#3132**

**Monito**  
via email

## >>> ANSWERS

**[#10125 - October 2012]**

### Android Platform

Are there any companies that are developing an Android device that is designed to be wall or panel mounted? I like the operating system and would like to integrate an Android tablet into some automation, but haven't found anything online. My employer would also like to explore some possibilities for industrial applications and a panel mount would work best for them, too.

While it is not exactly a wall mounted product, the Arduino ADK (Android Development Kit) is built to interface with the Android platform. I hear that the Raspberry Pi is close to being able to run Android and that might be an interesting alternative.

**playinmyblues**  
via email

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**[#1131 - January 2012]**

### Microcontroller Newbie

I'm just starting in electronics and have taught myself some of the basics through reading books and building kits. I'm intrigued with microcontroller projects and was hoping to get some seasoned opinions on where to start. There seem to be several popular platforms that get most of the attention such as Arduino, PIC, Stamp, Propeller, etc.

Which is best for a beginner?

Can someone recommend a book on programming that assumes zero experience and explains the basics from the start through getting a simple project up and running?

Are there any beginner-friendly online user groups I might join?

Any advice is appreciated.

**#1** There are a number of ways to get started in MCUs.

In my opinion, Parallax has the best documentation to use for getting started. If you don't want to buy their packages, you can download the pdfs and source the parts after looking at the components, which they provide in one nice place in their books. If you use a book such as the StampWorks book, then you should examine the schematics for their Professional Development Board (BS2 version and not the Propeller version), and buy the necessary components to build the experiments. Other BS2 versions are available such as the Stamp Stack II. The "What's a Microcontroller" pdf is also a good starting point.

by readers and **NO GUARANTEES WHATSOEVER** are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals.

*Always use common sense and good judgment!*

## >>>YOUR ELECTRONICS QUESTIONS ANSWERED HERE BY N&V READERS

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or via the online form at [www.nutsvolts.com/tech-forum](http://www.nutsvolts.com/tech-forum)

All the concepts you learn with any MCU system will be able to be applied to any other system. The syntax and instructions will vary but the concepts remain the same. Arduino has a number of books written about it and is probably the most popular among those who know little about MCUs. It was made with artists and builders in mind, not for engineers and tech-like people. They have done a good job of marketing and there are many applications made accessible through their "shield" format. Of course, there are quite a few books written about Arduino and you should examine whichever book to find out what parts you will need to work with the projects.

The PICAXE is also fairly popular and is programmed in a version of Basic. The Propeller is supposed to be a little more advanced as are AVRs, PICs, and other major companies' MCUs that are mostly programmed in C. For a beginner, I would stay away from the Propeller, AVRs, and PICs as there will probably be too steep a learning curve. The BASIC Stamp 2 is a little more expensive as you will need the MCU and, if it is not a USB version, you will also need a USB to RS-232 converter — unless you have a PC with the old serial port, DB9 style.

The Arduino is cheaper and more popular, but you will most likely have to do a little more searching and trial and error to get your code running with the documentation available. Parallax (the company that makes the BS2) has very good documentation. Another advantage of the Arduino is that programs written in C/C++ will also work in the Arduino environment.

Books for the BS2: *What's a Microcontroller?* and *StampWorks*."

Books for Arduino: the Evil Genius books and probably *Arduino Cookbook*.

Books for the PICAXE: Unknown but there are bound to be some on the PICAXE homepage, as well as Amazon.

**playinmyblues**  
via email

#2 I'm also at a similar beginning stage, as you describe. I am currently working through a book called *C Programming for Embedded Microcontrollers* by Warwick A. Smith, which I find thus far to be excellent. The ISBN is 978-0-905705-80-4.

Here are the books, features, and recommendations:

Use only free or open source software.

Learn how to download, set up, and use free C programming tools.

Start learning the C language to write simple PC programs before tackling embedded programming — *No need to buy an embedded system right away!*

Start learning to program from the very first chapter with simple programs and slowly build from there. No programming experience is necessary!

*Learn by doing* — Type and run the example programs and exercises which can be downloaded from the Internet. — *A fun way to learn the C programming language.*

Ideal for electronic hobbyists, students and engineers wanting to learn the C programming language in an embedded environment on ARM microcontrollers.

As a beginner, I personally found Arduino to be the easiest platform to get a running start.

**Agg**  
via email

### [#2132 - Februsry 2013] **Inductive Kick Diode**

I built a PWM controller for a 36 volt golf cart motor. What size, amperage, and voltage do I need for the motor's fly-back diode?

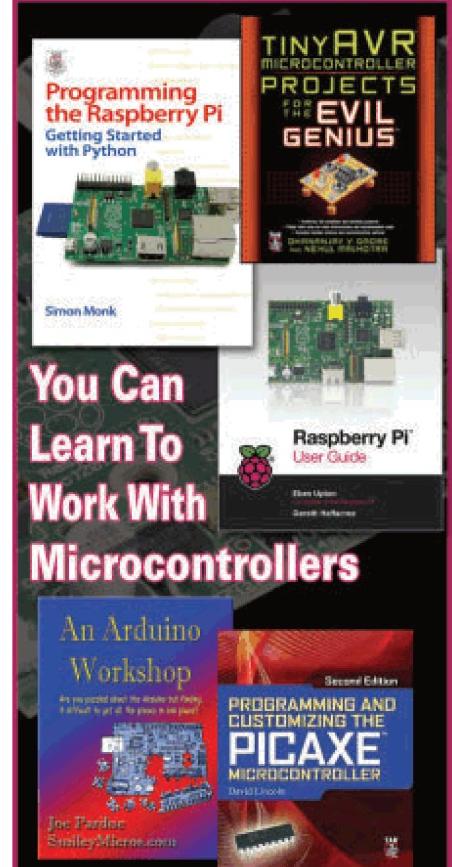
The maximum reverse voltage across the diode will be 36 volts. A conservative rule of thumb is to double that, so choose a diode with a rating of at least 72 volts. The maximum current will be whatever your PWM controller delivers to the motor. When the PWM controller shuts off at the end of each cycle, the voltage

across the motor inductance will instantaneously reverse polarity and begin to flow through the diode. Using the same rule of thumb, pick a diode that is rated for twice this current. You also need to be sure the diode can dissipate the power while keeping its junction temperature below TJ max (150 deg C is typical). The power dissipated is  $1/2 L I^2$  (the energy stored in the motor inductance) multiplied by the frequency of your PWM controller. Depending on this result, you may need to put the diode on a heatsink.

**Mark Whitmore**  
**Frederick, MD**

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**CHIP ADAPTERS**

EZPrototypes .....59

**CIRCUIT BOARDS**AP Circuits .....28  
Cunard Associates .....31  
Dimension Engineering.....73  
ExpressPCB .....39  
Front Panel Express LLC ...28  
PCB Pool .....71  
Saelig Company Inc. .....71  
Target-3001.com .....9**COMPONENTS**Cana Kit Corp. .....7  
Electronix Express .....13**COMPUTER****Hardware**  
EZSBC .....22  
Weirdstuff Warehouse .....31**Microcontrollers / I/O****Boards**  
Abacom Technologies .....22  
microEngineering Labs.....38  
MikroElektronika .....3  
Pololu Robotics & Electronics ..5**Software**MakerPlot.com .....31  
Target-3001.com .....9**DESIGN/ENGINEERING/  
REPAIR SERVICES**Cana Kit Corp. .....7  
ExpressPCB .....39  
Front Panel Express LLC ...28  
PCB Pool .....71  
Target-3001.com .....9**EDUCATION**Command Productions .....29  
NKC Electronics .....31  
Poscope .....21**EMBEDDED TOOLS**

NetBurner .....2

**ENCLOSURES**

Front Panel Express LLC ...28

**EVENTS**Trenton Computer Show ....48  
RoboGames .....30**GRAPHICAL PLOTTING  
SOFTWARE**

MakerPlot.com .....31

**GUI FOR****MICROCONTROLLERS**

MakerPlot.com .....31

**KITS & PLANS**Cana Kit Corp. .....7  
Jaycar Electronics ...Back Cover  
NetBurner .....2  
NKC Electronics .....31  
QKITS .....31  
Ramsey Electronics .....82-83**MISC./SURPLUS**All Electronics Corp. .....4  
Front Panel Express LLC ...28  
Weirdstuff Warehouse .....31**PROGRAMMERS**microEngineering Labs.....38  
MikroElektronika .....3**PROTOTYPE BOARDS**

EZPrototypes .....59

**RF TRANSMITTERS/  
RECEIVERS**Abacom Technologies .....22  
9**ROBOTICS**EZSBC .....22  
Lemos International Co., Inc. .31  
Pololu Robotics & Electronics ..5  
Robot Power .....31  
RobotShop Inc. .....49, 81**SATELLITE**

Lemos International Co., Inc. .31

**SOLDERING STATIONS  
AND IRONS**

HAKKO .....23

**TEST EQUIPMENT**Dimension Engineering.....73  
Electronic Design Specialists 73  
Jaycar Electronics ...Back Cover  
NKC Electronics .....31  
Pico Technology.....19  
Poscope .....21  
Saelig Company Inc. .....71**TOOLS**HAKKO .....23  
Handheld Scientific Inc. .....39  
MikroElektronika .....3  
NetBurner .....2  
PanaVise .....72  
Poscope .....21**WIRE, CABLE AND  
CONNECTORS**

EZPrototypes .....59

**WIRELESS PRODUCTS**

Handheld Scientific Inc. .....39

Abacom Technologies .....22

All Electronics Corp. .....4

AP Circuits .....28

Cana Kit Corp. .....7

Command Productions .....29

Cunard Associates .....31

Dimension Engineering.....73

Electronic Design Specialists 73

Electronix Express .....13

ExpressPCB .....39

EZPrototypes .....59

EZSBC .....22

Front Panel Express LLC ...28

HAKKO .....23

Handheld Scientific Inc. .....39

Jaycar Electronics ...Back Cover

Lemos International Co., Inc. .31

MakerPlot.com .....31

microEngineering Labs.....38

MikroElektronika .....3

NetBurner .....2

NKC Electronics .....31

Pico Technology.....19

PanaVise .....72

PCB Pool .....71

Pico Technology.....19

Pololu Robotics &amp; Electronics ..5

Poscope .....21

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The FM100B series includes an attractive metal case, whip antenna and built in 110/220VAC power supply. A BNC connector is also provided for an external antenna. Check out our Tru-Match FM antenna kit, for the perfect mate to the FM100B transmitter.

We also offer a high power kit as well as an export-only assembled version that provides a variable RF output power up to 1 watt. The 1 watt unit must utilize an external antenna properly matched to the operating frequency to maintain a proper VSWR to protect the transmitter. (Note: The FM100B and FM100BEX are do-it-yourself learning kits that you assemble. The end user is responsible for complying with all FCC rules & regulations within the US or any regulations of their respective governing body. The FM100BWT is for export use and can only be shipped to locations outside the continental US, valid APO/FPO addresses or valid customs brokers for documented end delivery outside the continental US).

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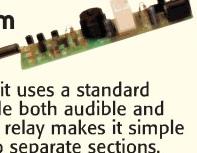
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- PCB: 69 x 51mm

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- PCB: 75 x 47mm

**Cat. KC-5518**



\$21.75\*



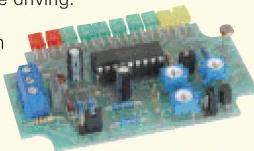
### Display Kits for Cars

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- 12VDC
- PCB: 74 x 47 mm
- Recommended box: UB5 (use HB-6015 \$2.00)

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\$16.75\*

#### Universal Voltage Switch Kit

A universal module suits a range of different applications. It will trip a relay when a preset voltage is reached. Can be configured to trip with a rising or falling voltage making it suitable for a wide variety of voltage outputting devices eg., throttle position sensor, air flow sensor, EGO sensor. It also features adjustable hysteresis (the difference between trigger on/off voltage), making it extremely versatile. You could use it to trigger an extra fuel pump under high boost, anti-lag wastegate shutoff, and much more.

- Kit supplied with PCB, and electronic components.
- PCB: 105 x 60mm

**Cat. KC-5377**



\$23.75\*

#### Speedo Corrector Kit MkII

When you modify your gearbox, diff ratio or change to a large circumference tyre, it may result in an inaccurate speedometer. This kit alters the speedometer signal up or down from 0% to 99% of the original signal. The input setup selection can be automatically selected and features an LED indicator to show when the input signal is being received. Kit supplied with PCB with overlay and all electronic components.

- PCB: 105 x 61mm
- Recommended box: UB3 (use HB-6013 \$2.50)

**Cat. KC-5435**



\$39.75\*

#### Automotive Headlight Reminder Kit

Features include a modulated alarm, ignition and lights monitoring, optional door switch detection, time-out alarm and a short delay before the alarm sounds. Kit includes quality solder masked PCB with overlay, case with screen printed lid and all electronic components.

- 12VDC
- PCB: 78 x 49 mm

**Cat. KC-5317**

\$20.25\*



#### Economy Adjustable Temperature Switch Kit

Features an adjustable switching temperature up to 475°C, and it can be configured to trigger with rising or falling temperature. It has adjustable hysteresis (the difference between on/off temp) which is a great feature many other units do not possess. It can be used to operate cooling fans on a radiator or amplifier, over-temp warning lights or alarms, and much more. The small temperature sensor reacts quickly to temp changes.

- Kit supplied with PCB, NTC Thermistor, and all electronic components
- PCB: 105 x 60mm

**Cat. KC-5381**

\$23.75\*

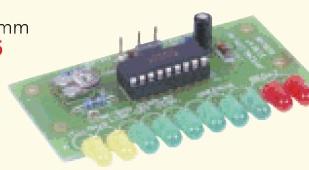


#### Mixture Display Kit for Fuel Injected Cars

This very simple kit will allow you to monitor the fuel mixtures being run by your car. This type of sensor is also known as an E.G.O. (exhaust, gas, oxygen) monitor. The circuit connects to the EGO sensor mounted in the exhaust manifold and the car's battery. PCB, LEDs and components supplied.

- PCB: 74 x 36mm

**Cat. KC-5195**



\$12.25\*

5-10  
working day  
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Best  
Seller!

#### Theremin Synthesiser Kit MkII

Create your own eerie science fiction sound effects by simply moving your hand near the antenna. Easy to set up and build. Complete kit contains PCB with overlay, pre-machined case and all specified components.

- PCB: 85 x 145mm

**Cat. KC-5475**

\$54.00\*



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